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A

# NEW TREATISE

ON THE

# USE OF THE GLOBES;

OR,

# A PHILOSOPHICAL VIEW

OF

# THE EARTH AND HEAVENS:

COMPREHENDING

AN ACCOUNT OF THE FIGURE, MAGNITUDE, AND MOTION OF THE EARTH; WITH
THE NATURAL CHANGES OF ITS SURFACE, CAUSED BY FLOODS, EARTHQUAKES, &C. TOGETHER WITH THE PRINCIPLES OF METEOROLOGY, AND ASTRONOMY; WITH THE THEORY OF
THE TIDES, ETC.

PRECEDED BY

AN EXTENSIVE SELECTION OF ASTRONOMICAL, AND OTHER DEFINITIONS; AND
ILLUSTRATED BY A GREAT VARIETY OF PROBLEMS, QUESTIONS FOR
THE EXAMINATION OF THE STUDENT, ETC. ETC.

DESIGNED FOR THE INSTRUCTION OF YOUTH.

BY THOMAS KEITH.

REVISED AND CORRECTED,
BY ROBERT ADRIAN, LL.D.; F.A.P.S.; F.A.A.S., &c.
AND PROFESSOR OF MATHEMATICS IN RUTGER'S COLLEGE,
NEW BRUNSWICK, NEW JERSEY.

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BE IT REMEMBERED, That on the Seventeenth day of July,, A.D. 1826, in the fifty-first year of the Independence of the United States of America, Samuel Wood & Sons, of the said District, hath deposited in this office, the title of a book, the right whereof they claim as proprietors, in the words following, to wit:

A new Treatise on the Use of the Globes, or a Philosophical View of the Earth and Heavens: comprehending an account of the figure, magnitude, and motion of the earth; with the natural changes of its surface, caused by floods, earthquakes, &c. together with the principles of meteorology, and astronomy; with the theory of the tides, &c. Preceded by an extensive selection of astronomical and other definitions; and illustrated by a great variety of problems, questions for the examination of the student, &c. &c. designed for the instruction of youth. By Thomas Keith. The fourth American from the last London edition. Revised and corrected by Robert Adrain, LL.D.; F A.P.S.; F.A.A.S., &c. and professor of mathematics in Rutger's College, New Brunswick, New Jersey.

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JAMES DILL,
Clerk of the Southern District of New-York.

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# PREFACE.

Amongst the various branches of science studied in our academies, and places of public education, there are few of greater importance than that of the Use of the Globes. The earth is our destined habitation, and the heavenly bodies measure our days and years by their various revolutions. Without some acquaintance with the different tracts of land, the oceans, seas, &c. on the surface of the terrestrial globe, no intercourse could be carried on with the inhabitants of distant regions, and consequently their manners, customs, &c. would be totally unknown to us. Though the different tracts of land, &c. cannot be so minutely described on the surface of a terrestrial globe as on different maps; yet the globe shows the figure of the earth and the relative situations of the principal places on its surface, more correctly than a map. Had the ancients paid no attention to the motions of the heavenly bodies, historical facts would have been given without dates, and we should have had neither dials, clocks, nor watches. To the celestial observations of Eudoxus, Hipparchus, &c. we are indebted for the knowledge of the precession of the equinoxes. Without some acquaintance with the celestial bodies our ideas of the power and wisdom of the Creator would be greatly circumscribed and confined. The learned and pious Dr. Watts observes, "What wonders of Wisdom are seen in the exact regularity of the revolutions of the heavenly bodies! Nor was there ever any thing that has contributed to enlarge my apprehensions of the immense power of God, the magnificence of his creation, and his own transcendent grandeur, so much as the little portion of astronomy which I have been able to attain. And I would not only recommend it to young students, for the same purposes, but I would persuade all mankind, if it were possible, to gain some degree of acquaintance with the vastness, the distances, and the motions of the planetary worlds, on the same account."

Dr. Young, in his Night Thoughts, says,

> "An undevout Astronomer is mad."

There is scarcely a writer on the different branches of education who has not expressly recommended the study of the globes. Milton observes that "ere half the school authors be read, it will be seasonable for youth to learn the use of the globes." Yet notwithstanding the importance of the subject, it is entirely neglected in our public schools; and in many of our private academies it has been frequently imperfectly taught; probably for want of a treatise sufficiently comprehensive in its object, and illustrated by a suitable number of examples.

There are several treatises on the globes extant, but they have been chiefly written by mathematical instrument makers,* or by

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* The addition of a few wires, a semicircle of brass, a particular kind of hour circle, &c. which is of no other use on the globe than to enhance the price thereof, has generally been a sufficient inducement for the instrument maker to publish a treatise explanatory of the use of such addition. The more simply the globes are fitted up, and the less they are encumbered with useless wires, &c. the more easily they will be understood by the generality of learners. The most important part of a globe is its external surface: if the *places* on the terrestrial globe, and the *stars* on the celestial, be accurately laid down, and distinctly and clearly engraven, it is of little consequence of what materials the frame is made.

The principal globe makers in London are Cary, Bardin, Newton, and Addison.

Cary's globes are 21 inches, 18 inches, 15 inches, 12 inches, and 9 inches in diameter, and the celestial globe may be purchased either with or without the hieroglyphical figures depicted on the surface.

Bardin's globes, or, as they are usually called, the New British Globes, are 18 inches, and 12 inches in diameter. The New British Globes, manufactured teachers unacquainted with mathematics. The works of the former must be defective for want of practice in the art of teaching; and many of the productions of the latter are too peurile and trifling to be introduced into a respectable academy. Youth learn nothing effectually, but by frequent repetition; a multiplicity of examples therefore becomes absolutely necessary; but these examples should be so varied, and the mode of proposing the questions so diversified, as to give the scholar room for the exertion of his faculties, or otherwise no impression will remain on his mind. Treatises on the globes are generally either without any practical exercises; or the exercises are so similar, that when the pupil has finished one of them, the rest may be performed without the trouble of thinking. Examples of this kind may serve to pass away the time, but they will never instruct the scholar.

Had any mathematical writer of note furnished the student with a treatise on the globes, the following work would probably have never appeared; but it rarely happens that the man of science, whose whole time is employed in abstruse researches, will stoop to the humble task of accommodating himself to the capacity of a learner. To a man in the habit of contemplating the

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mended by Mr. Vince, in vol. i. page 569, of his complete System of Astronomy, and were introduced into the Royal Observatory at Greenwich, by the late *Dr. Maskelyne.*

NEWTON's globes are 15 inches, and 12 inches in diameter. The horizon on these globes is the same as on Bardin's; only, instead of the signs of the zodiac, the ecliptic and zodiacal constellations are introduced. The analemma on the surface is not essentially different from that on Cary's globes.

ADDISON's globes are 18, 12, and 10 inches in diameter. The analemma on the surface of these globes is the same as the analemma on Cary's globes. Mr. Addison is now constructing a superb pair of globes, 36 inches in diameter.

WILSON's AMERICAN GLOBES are 13 inches, 9 inches, and 3 inches in diameter. They are used in academies generally in preference to any others, as they are quite equal to the best English in the execution of the plates; more correct in the geographical divisions of the western continent; and can be purchased at less prices.

writings of a Newton, or travelling in the dry and difficult paths of abstract knowledge, a treatise on the globes is a mere plaything, a trifle not worth notice; as at one glance he sees and comprehends every problem that can be performed by them. Such a man would acquire no credit by writing a Treatise on the Globes; for, notwithstanding the utility of the subject, its simplicity would leave no room for him to display his abilities: the task, therefore, necessarily devolves on writers of a more humble rank.

The ensuing Treatise has been formed entirely from the practice of Instruction, and is arranged in the following order:

Part I. The definitions are very extensive, and, it is hoped, sufficiently plain and clear. Where the name of any ancient author occurs, the time in which he flourished, and his country, are generally mentioned in a note; this practice is followed throughout the book. The table of climates has been newly calculated, and the principle of calculation is given at full length. The *first chapter* likewise contains a table of the constellations, with the fabulous history of several of them; the Greek alphabet, &c. If the definitions, geographical theorems, &c. in this chapter be well explained by the tutor, it is presumed that the scholar will derive considerable advantage. The *second chapter* contains the general properties of matter, and the laws of motion, as preparatory to the reading of the third and fourth chapters; which would otherwise be less intelligible. To the *third* and *fourth chapters* are added some useful notes, which ought to be attended to by those students who are acquainted with arithmetic. The *fifth chapter* treats of springs, rivers, and the saltness of the sea; the *sixth* of the tides; and the *seventh* of earthquakes, &c. with their effects and causes. The subject of the *eighth chapter* is the atmosphere, and of the *ninth*, meteorology. From each of these chapters, it is hoped, the student will derive some useful information.

It has not been usual to introduce several of the aforesaid subjects into a Treatise on the Globes. An intelligent reader will, however, readily admit them to be less extraneous, equally entertaining, and more instructive than scraps of poetry, historical anecdotes, &c. with which some of our Treatises on the Globes abound. Poetical scraps seldom elucidate either mathematical or philosophical subjects, and generally divert the attention of the student from the main object of his pursuit.

Part II. This part comprehends the elementary principles of Astronomy, including an account of the solar system. These ought to be clearly understood by the young student before he attempts to solve many of the problems in the succeeding parts of the book. The object in learning the Use of the Globes should be to illustrate some of the most important branches of geography and astronomy; and this object can not be attained by merely twirling the globe around and working a few problems, without understanding the principles on which their solutions are founded. Lessons thoroughly explained and clearly understood make a lasting impression on the student's memory, and will enable him not only to solve such problems as he may meet with in books on the Globes, but to frame several new problems himself, and to solve others of which he never heard before.

In the notes attached to this part of the following work, the distances, magnitudes, &c, of the planets are all accurately calculated. This laborious task the author would gladly have avoided, but he found the accounts of the distances, magnitudes, &c. of the planets so variable and contradictory, even in astronomical works of repute, and frequently in the same author, that he conceived such notes as he has introduced would be very useful to a learner.

Part III. Contains an extensive collection of Problems; illustrated by a great number of useful examples, many of which are elucidated with notes of considerable importance.

Part IV. Comprehends a miscellaneous selection of Problems, and Questions for the examination of the student. These questions will be found very useful, and may be extended with advantage by the tutor.

To Conclude. The author apprehends that he has omitted nothing of importance that particularly relates to the subject, and he hopes, at the same time, that this work will be found to contain little or no extraneous matter. He has endeavoured to supply the young student with a Treatise on the Globes, which may not be unworthy of attention, as a work of science, yet sufficiently plain and intelligible.

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A new plate was delineated for the *second edition* of this work showing the path of the planet Jupiter in the Zodiac, for the year 1811, which will likewise answer nearly for the year 1823, together with the constellations and principal stars through which he passes, agreeably to their appearance in the heavens. Delineations of this kind will not only prove amusing, but instructive to the scholar, as they give a more correct idea of the relative situations of the stars than a globe.

By laying down on paper all the principal constellations from the celestial globe, as directed in Problem CII.; rejecting such stars as are smaller than those of the fourth magnitude, and those constellations which do not come above the horizon, the young student will soon render the appearance of the heavens familiar to him.

To the *present edition* several wood cuts and a new copperplate have been added; the whole has been carefully revised and enlarged by a considerable quantity of additional matter, with a view of rendering it as complete and comprehensive as possible. 1826.

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A

# NEW TREATISE

ON THE

# USE OF THE GLOBES, &C.

## PART I.

DEFINITIONS AND INTRODUCTORY SUBJECTS.

## CHAPTER I.

*Explanation of the Lines on the Artificial Globes, including Geographical and Astronomical Definitions; with a few Geographical Theorems.*

1. THE **Terrestrial Globe** is an artificial representation of the earth. On this globe the four quarters of the world, the different empires, kingdoms and countries; the chief cities, seas, rivers, &c. are truly represented, according to their relative situation on the real globe of the earth. The diurnal motion of this globe is from west to east.

2. The **Celestial Globe** is an artificial representation of the heavens, on which the stars are laid down in their natural situations. The diurnal motion of this globe is from east to west, and represents the apparent diurnal motion of the sun, moon, and stars. In using this globe, the student is supposed to be situated in the centre of it, and viewing the stars in the concave surface.

3. The **Axis of the Earth** [*See Plate* I. **Figures* I. *and* II.]

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* Figure I. represents the frame of the globe, with the horizon, brass meridian, and axis: Figure II. the Globe itself, with the lines on its surface.

is an imaginary line passing through the centre of it, upon which it is supposed to turn, and about which all the heavenly bodies appear to have a diurnal revolution. This line is represented by the wire which passes from north to south, through the middle of the artificial globe.

4. The **Poles of the Earth** are the two extremities of the axis, where it is supposed to cut the surface of the earth, one of which is called the north, or arctic pole; the other, the south, or antarctic pole. The celestial poles are two imaginary points* in the heavens, exactly above the terrestrial poles.

5. The **Brazen Meridian** is the circle in which the artificial globe turns, and is divided into 360 equal parts, called degrees.† In the upper semicircle of the brass meridian these degrees are numbered from 0 to 90, from the equator towards the poles, and are used for finding the latitudes of places. On the lower semicircle of the brass meridian they are numbered from 0 to 90, from the poles towards the equator, and are used in the elevation of the poles.

6. **Great Circles** divide the globe into two *equal* parts, as the equator, ecliptic, and the colures.

7. **Small Circles** divide the globe into two unequal parts, as the tropics, polar circles, parallels of latitude, &c.

8. **Meridians**, or Lines of Longitude, are *semicircles*, extending from the north to the south pole, and cutting the equator at right angles. Every place upon the globe is supposed to have a meridian passing through it, though there be only 24 drawn upon the terrestrial globe; the deficiency is supplied by the brass meridian. When the sun comes to the meridian of any place, it is noon at that place.

9. The **First Meridian** is that from which geographers begin to count the longitudes of places. In English maps and globes the first meridian is a semicle supposed to pass through London, or the royal observatory at Greenwich.

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* The polar star is a star of the second magnitude, near the north pole, in the end of the tail of the Little Bear. Its mean right ascension, for the beginning of the year 1820, is 14° 13′ 7″; and its declination 88° 20′ 55″ N. *Connoissance des Tems*, for 1820, p. 168.

† Every circle is supposed to be divided into 360 equal parts called degrees; each minute, into 60 equal parts called seconds, &c.: (a degree therefore is of different lineal extent, according to the magnitude of the circumference to which it belongs. A degree of a great circle of the earth, as of the meridian or equator, contains 60 geographical miles or 69 1-10 English miles.) A degree of a great circle in the heavens is a space nearly equal to twice the apparent diameter of the sun or moon.

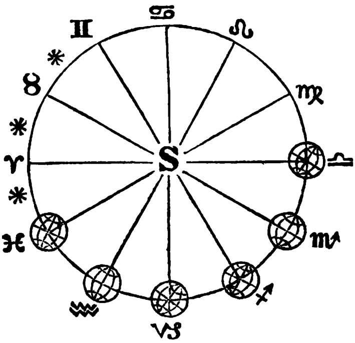
Degrees are marked with a small cipher, minutes with *one* dash, seconds with *two*, thirds with *three*, &c. Thus 25° 14′ 22″ 35‴, are read 25 degrees, 14 minutes, 22 seconds, 35 thirds.

10. The **Equator** is a great circle of the earth, equi-distant from the poles, and divides the globe into two hemispheres, northern and southern. The latitudes of places are counted *from* the equator, northward and southward; and the longitudes of places are reckoned *upon* it, eastward and westward.

The equator, when referred to the heavens, is called the *equinoctial,* because when the sun appears in it, the days and nights are equal all over the world, viz. 12 hours each. The declinations of the sun, stars, and planets, are counted *from* the equinoctial northward and southward, and their right ascensions are reckoned *upon* it eastward round the celestial globe from 0 to 360 degrees.

11. The **Ecliptic** is a great circle in which the sun makes his apparent annual progress among the fixed stars[*]; or, it is the great circle in the plane of which is situated the real path of the earth round the sun, and cuts the equinoctial in an angle of 23° 28′; the points of intersection are called the equinoctial points. The ecliptic is situated in the middle of the zodiac.

To show that the great circle in the plane of which is situated the *real* path of the earth round the sun is the same as the *apparent* path of the sun among the fixed stars, let S represent the sun; when the earth is in ≏ *Libra,* the sun will appear in ♈ *Aries;* when the earth is in ♏ *Scorpio,* the sun will appear in ♉ *Taurus;* when the earth is in ♐ *Sagittarius,* the sun will appear in ♊ *Gemini;* and so on round the ecliptic. The eye cannot judge of distances beyond a certain limit; hence the heavenly bodies, viz. the sun, stars, and the moon, all appear *equally* remote from a spectator on the earth.



12. The **Zodiac**, on the celestial globe, is a space which extends about eight degrees on each side of the ecliptic, like a belt or girdle, within which the motions of all the planets[†] are performed.

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[*] The sun's apparent *diurnal path* is either in the equinoctial or in lines nearly parallel to it; and his apparent *annual path* may be traced in the heavens, by observing what particular constellation in the zodiac is on the meridian at midnight; the opposite constellation will show, very nearly, the sun's place at noon on the same day.

[†] Except the new discovered planets, or Asteroids, *Ceres* and *Pallas.*

13. **Signs of the Zodiac.** The ecliptic and zodiac are divided into 12 equal parts, called signs, each containing 30 degrees. The sun makes his apparent annual progress through the ecliptic, at the rate of nearly a degree in a day. The names of the signs, and the days on which the sun enters them, are as follows: 13

| Spring Signs. | Summer Signs. |
|---|---|
| ♈ *Aries*, the Ram, 21st of March. | ♋ *Cancer*, the Crab, 21st of June. |
| ♉ *Taurus*, the Bull, 19th of April. | ♌ *Leo*, the Lion, 22d of July. |
| ♊ *Gemini*, the Twins, 20th of May. | ♍ *Virgo*, the Virgin, 22d of August. |

These are called northern signs, being north of the equinoctial.

| Autumnal Signs. | Winter Signs. |
|---|---|
| ♎ *Libra*, the Balance, 23d of September. | ♑ *Capricornus*, the Goat, 21st of December. |
| ♏ *Scorpio*, the Scorpion, 23d of October. | ♒ *Aquarius*, the Water-bearer, 20th of January. |
| ♐ *Sagittarius*, the Archer, 22d of November. | ♓ *Pisces*, the Fishes, 19th of February. |

These are called southern signs.

The winter and spring signs are called *ascending* signs, and the summer and autumnal signs are called descending signs.

14. The **Colures** are two great circles passing through the poles of the world; one of them passes through the equinoctial points, Aries* and Libra; the other, through the solstitial points, Cancer and Capricorn; hence they are called the equinoctial and solstitial colures. They divide the ecliptic into four equal parts, and mark the four seasons of the year.

15. **Declination** of the sun, of a star, or planet, is its distance from the equinoctial, northward or southward. When the sun is in the equinoctial he has no declination, and enlightens half the globe from pole to pole. As he increases in north declination he

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* In the time of *Hipparchus* the equinoctial colure is supposed to have passed through the middle of the *constellation* Aries. Hipparchus was a native of Nicæa, a town of Bythinia, in Asia Minor, adout 75 miles S. E. of Constantinople, now called Isnic; he made his observations between 160 and 135 years before Christ.

gradually shines farther over the north pole, and leaves the south pole in darkness: in a similar mannner, when he has south declination, he shines over the south pole, and leaves the north pole in darkness. The greatest declination the sun can have is 23° 28′; the greatest declination a star can have is 90°; and that of a planet 30° 28′* north or south.

16. The TROPICS are two small circles, parallel to the equator (or equinoctial), at the distance of 23° 28′ from it; the northern is called the Tropic of Cancer, the southern the Tropic of Capricorn. The tropics are the limits of the torrid zone, northward and southward.

17. The POLAR CIRCLES are two small circles, parallel to the equator (or equinoctial), at the distance of 66° 32′ from it, and 23° 28′ from the poles. The northern is called the *arctic*, the southern the *antarctic* circle.

18. PARALLELS OF LATITUDE are small circles drawn through every ten degrees of latitude, on the terrestrial globe, parrallel to the equator. Every place on the globe is supposed to have a parrallel of latitude drawn through it, though there are generally only *sixteen* parallels of latitude drawn on the terrestrial globe.

19. The HOUR CIRCLE on the artificial globes is a small circle of brass, with an index or pointer fixed to the north pole; it is divided into 24† equal parts, corresponding to the hours of the day, and these are again subdivided into halves and quarters. The hour circle, when placed *under* the brass meridian, is moveable round the axis of the globe, and the brass meridian, in this case, answers the purpose of an index.

20. The HORIZON is a great circle which separates the visible half of the heavens from the invisible; the earth being considered as a point in the centre of the sphere of the fixed stars. Horizon, when applied to the earth, is either *sensible* or *rational.*

21. The SENSIBLE, or visible horizon, is the circle which

---

* Except the planets, or Asteroids, *Ceres* and *Pallas*, which are nearly at the same distance from the sun; the former, in April 1802, was out of the zodiac, its latitude being 15° 20′ N.

† Some globes have two rows of figures on the index, others but one. On *Bardin's New British Globes* there is an hour circle at each pole, numbered with two rows of figures. On Adams' common globes there is but one index; and on his improved globes the hours are counted by a brass wire with two indexes standing over the equator. The form of the hour circle is, however, a matter of little consequence, (provided it be placed *under* the brass meridian,) as the equator will answer every purpose to which a circle of this kind can be applied.

bounds our view, where the sky appears to touch the earth or sea.*

22. The **Rational**, or true horizon, is an imaginary plane, passing through the centre of the earth parrallel to the sensible horizon. It determines the rising and setting of the sun, stars, and planets.

23. The **Wooden Horizon**, circumscribing the artificial globe, represents the rational horizon on the real globe. This horizon is divided into several concentric circles, which on *Bardin's*† *New British Globes* are arranged in the following order:

*The First* is marked amplitude, and is numbered from the east towards the north and south, from 0 to 90 degrees, and from the west towards the north and south in the same manner.

*The Second* is marked azimuth, and is numbered from the north point of the horizon towards the east and west, from 0 to 90 degrees; and from the south point of the horizon towards the east and west in the same manner.

*The Third* contains the thirty-two points of the compass, divided into half and quarter points. The degrees in each point are to be found in the amplitude circle.

*The Fourth* contains the twelve signs of the zodiac, with the figure and character of each sign.

*The Fifth* contains the degrees of the signs, each sign comprehending 30 degrees.

*The Sixth* contains the days of the month answering to each degree of the sun's place in the ecliptic.

*The Seventh* contains the equation of time, or difference of time shown by a well-regulated clock and a correct sun-dial. When the clock ought to be faster than the dial, the number of minutes, expressing the difference, is followed by the sign +; when the clock or watch ought to be slower, the number of minutes in the difference is followed by the sign —. This circle is peculiar to the *New British Globes.*

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* The sensible horizon extends only a few miles; for example, if a man of 6 feet high were to stand on an extensive level, or on the surface of the sea; the utmost extent of his view, upon the earth or the sea, would be about three miles. Thus, if $h$ be the height of the eye above the surface of the sea, and $d$ the diameter of the earth in feet, then

$\sqrt{d + h + h}$, will nearly show the distance which a person will be able to see, straght forward. *Keith's* Trigonometry, Fourth Edition, Example XLV. page 82.

† Cary's Globes have a different division of the wooden horizon. The first circle, or that nearest to the globe, is numbered from the east and west towards the north and south, from 0 to 90°. The second contains the thirty-two points of the compass: The third, the signs of the zodiac: The fourth, the degrees of the signs: The fifth, the days of the months: The sixth, the names of the months.

*The Eighth* contains the twelve calender months.

24. The CARDINAL POINTS of the horizon are east, west, north, and south.

25. The CARDINAL POINTS in the heavens are the zenith, the nadir, and the points where the sun rises and sets.

26. The CARDINAL POINTS of the ecliptic are the equinoctial and solstitial points, which mark out the four seasons of the year; and the *Cardinal signs* are ♈ Aries, ♋ Cancer, ♎ Libra, and ♑ Capricorn.

27. The ZENITH is a point in the heavens exactly over our heads, and is the elevated pole of our horizon.

28. The NADIR is a point in the heavens exactly under our feet, being the depressed pole of our horizon, and the zenith, or elevated pole, of the horizon of our antipodes.

29. The POLE of any circle is a point on the surface of the globe, 90 degrees distant from every part of that circle of which it is the pole. Thus the poles of the earth are 90 degrees from every part of the equator; the poles of the ecliptic (on the celestial globe) are 90 degrees from every part of the ecliptic, and 23° 28′ from the poles of the equinoctial, consequently they are situated in the arctic and antarctic circles. Every circle on the globe, whether real or imaginary, has two poles diametrically opposite to each other.

30. The EQUINOCTIAL POINTS are[*] Aries and Libra, where the ecliptic cuts the equinoctial. The point Aries is called the *vernal* equinox, and the point Libra the *autumnal* equinox. When the sun is in either of these points, the days and nights on every part of the globe are equal to each other.

31. The SOLSTITIAL POINTS are Cancer and Capricorn. When the sun is in, or near, these points, the variation in his greatest altitude is scarcely perceptible for several days; because the ecliptic near these points is almost parallel to the equinoctial, and therefore the sun has nearly the same declination for several days.—

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[*] The terms Aries, Libra, &c. primarily denoted the constellations of the zodiac: in the course of time they were also used to signify the twelve equal divisions of the ecliptic called signs; and in several works on the Globes and Astronomy, are employed to indicate the first points of these signs. This variety of signification is perplexing to beginners, and injurious to perspicuity: it is better to say that the equinoctial and solstitial points are the first points of the signs, Aries, Libra, &c.

When the sun enters Cancer, it is the longest day to all the inhabitants on the north side of the equator, and the shortest day to those on the south side. When the sun enters Capricorn it is the shortest day to those who live in north latitude.

32. A **Hemisphere** is half the surface of the globe; every *great circle* divides the globe into two hemispheres. The horizon divides the upper from the lower hemisphere in the heavens; the equator separates the northern from the southern on the earth; and the brass meridian, standing over any place on the terrestrial globe, divides the eastern from the western hemisphere.

33. The **Mariner's Compass** is a representation of the horizon, and is used by seamen to direct and ascertain the course of their ships. It consists of a circular brass box, which contains a paper card, divided into 32 equal parts, and fixed on a magnetical needle that always turns *towards* the north. Each point of the compass contains 11° 15′ or 11 1-4 degrees, being the 32d part of 360 degrees.

34. The **Variation of the Compass** is the deviation of its points from the corresponding points in the heavens. When the north point of the compass is to the east of the true north point of the horizon, the variation is east; if it be to the west, the variation is west.

The learner is to understand, that the compass does not always point *directly north*, but is subject to a small (irregular) annual variation. At present, in England, the needle points about 24½ degrees, to the westward of the north.

At London in

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1576, | the variation was, | 11° | 15′ | E. | 1747, | - - | 17° | 40′ | W. |
| 1612, | - - | 6 | 10 | E. | 1780, | - - | 22 | 10 | W. |
| 1623, | - - | 6 | 0 | E. | 1790, | - - | 23 | 39 | W. |
| 1634, | - - | 4 | 5 | E. | 1794, | - - | 23 | 54 | W. |
| 1657, | - - | 0 | 0 | | 1796, | - - | 24 | 0 | W. |
| 1666, | - - | 1 | 35 | W. | 1800, | - - | 24 | 2 | W. |
| 1683, | - - | 4 | 30 | W. | 1804, | - - | 24 | 8 | W. |
| 1700, | - - | 8 | 0 | W. | 1806, | - - | 24 | 8 | W. |
| 1722, | - - | 14 | 22 | W. | 1820, | - - | *24 | 34 | W. |

The compass is used for setting the artificial globe north and south; but care must be taken to make a prpper allowance for the variation.

35. **Latitude of a Place**, on the terrestrial globe, is its distance from the equator in degrees, minutes or geographical miles, &c. and is reckoned on the brass meridian, from the equator towards the north or south pole.

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36. **Latitude of a Star or Planet**, on the celestial globe, is its distance from the ecliptic, northward or southward, counted towards the pole of the ecliptic, on the quadrant of altitude. The greatest latitude a star can have is 90 degrees, and the greatest latitude of a planet is nearly 8 degrees.* The sun being always in the ecliptic, has no latitude.

37. The **Quadrant of Altitude** is a thin flexible piece of brass divided upwards from 0 to 90 degrees, and downwards from 0 to 18 degrees, and when used is generally screwed to the brass meridian. The upper divisions are used to determine the distances of places on the earth, the distances of the celestial bodies, their altitudes, &c., and the lower divisions are applied to finding the beginning, end, and duration of twilight.

38. **Longitude of a Place**, on the terrestrial globe, is the distance of the meridian of that place from the first meridian, reckoned in degrees and parts of a degree on the equator. Longitude is either eastward or westward, according as the place is eastward or westward of the first meridian. The greatest longitude that a place can have is 180 degrees, or half the circumference of the globe.

39. **Longitude of a Star, or Planet**, is reckoned on the ecliptic from the point Aries, eastward, round the celestial globe. The longitude of the sun is what is called the sun's place on the terrestrial globe.

40. **Almacantars**, or parallels of altitude, are *imaginary* circles parallel to the horizon, and serve to show the height of the sun, moon, or stars. These circles are not drawn on the globe, but they may be described for any latitude by the quadrant of altitude.

41. **Parallels of Celestial Latitude** are small circles drawn on the celestial globe, parallel to the ecliptic.

42. **Parallels of Declination** are small circles parallel to the equinoctial on the celestial globe, and are similar to the parallels of latitude on the terrestrial globe.

43. **Azimuth, or Vertical Circles**, are imaginary great circles passing through the zenith and the nadir, cutting the horizon at right angles. The altitudes of the heavenly bodies are measured on these circles, which circles may be represented by screwing the quadrant of altitude on the zenith of any place, and making the other end move along the wooden horizon of the globe.

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* The newly-discovered planets, or Asteroids, *Ceres* aad *Pallas*, *&c.* do not appear to be confined within this limit.

44. The PRIME VERTICAL is that azimuth circle which passes through the east and west points of the horizon, and is always at right angles to the brass meridian, which may be considered as another vertical circle passing through the north and south points of the horizon.

45. The ALTITUDE of any object in the heavens is an arc of a vertical circle, contained between the centre of the object and the horizon. When the object is upon the meridian, this arc is called the meridian altitude.

46. The ZENITH DISTANCE of any celestial object is the arc of a vertical circle, contained between the centre of that object and the zenith; or it is what the altitude of the object wants of 90 degrees. When the object is on the meridian, this arc is called the meridian zenith distance.

47. The POLAR DISTANCE of any celestial object is an arc of a meridian, contained between the centre of that object and the pole of the equinoctial.

48. The AMPLITUDE of any object in the heavens is an arc of the horizon, contained between the centre of the object when rising, or setting, and the east or west points of the horizon. Or, it is the distance which the sun or a star rises from the east, and sets from the west, and is used to find the variation of the compass at sea. When the sun has north declination, it rises to the north of the east, and sets to the north of the west; and when it has south declination, it rises to the south of the east, and sets to the south of the west. At the time of the equinoxes, when the sun has no declination, viz. on the 21st of March, and on the 23d of September, it rises exactly in the east, and sets exactly in the west.*

49. The AZIMUTH of any object in the heavens is an arc of the horizon, contained between a vertical circle passing through the object, and the north or south points of the horizon. The azimuth of the sun, at any particular hour, is used at sea for finding the variation of the compass.

50. HOUR CIRCLES, or HORARY CIRCLES, are the same as the meridians. They are drawn through every 15 degrees† of the

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[*] When the sun is in the equator at the instant of rising, he does not rise exactly due east, to places situated in north or south latitude, the difference being greater as the latitude increases: this difference is still greater with respect to the moon.

[†] On *Cary's* large Globes the meridians are drawn through every 10 degrees, as on a map.

equator, each answering to an hour—consequently, every degree of longitude answers to four minutes of time, every half degree to two minutes, and every quarter of a degree to *one* minute.

On the globes these circles are supplied by the brass meridian, the hour circle and its index.

51. The Six o'Clock Hour Line. As the meridian of any place, with respect to the sun, is called the 12 o'clock hour circle; so that great circle passing through the poles, which is 90 degrees distant from it on the equator, is called by astronomers the six o'clock hour circle, or the six o'clock hour line. The sun and stars are on the eastern half of this circle six hours before they come to the meridian; and on the western half six hours after they have passed the meridian.

52. Culminating Point of a star or planet is that point of its apparent diurnal path, which, on any given day, is the most elevated. Hence a star or planet is said to culminate when it comes to the meridian of any place; for then its altitude at that place is the greatest.

53. Apparent Noon is the time when the sun comes to the meridian; viz. 12 o'clock, as shown by a correct sun-dial.

54. Mean Noon, 12 o'clock, as shown by a well regulated clock, adjusted to go 24 hours in a *mean solar day*.

55. The Equation of Time at noon is the interval between the mean and apparent noon, viz. it is the difference of time shown by a well-regulated clock and a correct sun-dial.

56. An Apparent Solar Day is the time from the sun's leaving the meridian of any place, on that day, till it returns to the same meridian on the next day; viz. it is the time elapsed from 12 o'clock at noon, on any day, to 12 o'clock at noon on the next day, as shown by a correct sun-dial. An apparent solar day is subject to a continual variation, arising from the obliquity of the ecliptic, and the unequal motion of the earth in its orbit; the duration thereof sometimes exceeds, at others, falls short, of 24 hours, and the difference is the greatest about the 23d of December, when the apparent solar day is 30 seconds more than 24 hours, as shown by a well-regulated clock.

57. A Mean Solar Day is measured by equal motion, as by a clock or time-piece, and consists of 24 hours. There are in the course of a year as many mean solar days as there are apparent solar days, the slowness of the sun at certain seasons being compensated by his rapidity at others. The clock is faster than the sun-dial from the 24th of December to the 15th of April, and from the 16th of June to the 31st of August: but from the 15th of April to the 16th of June, and from the 31st of August to the 24th

of December, the sun-dial is faster than the clock. From the 2d of November to the 11th of February, the apparent solar day is greater than the mean solar day; from the 11th of February to the 15th of May, the apparent solar day is less than the mean. From the 15th of May to the 25th of July, the apparent is greater than the mean; and from the 25th of July to the 2d of November the apparent is less than the mean. On February 11th, May 15th, July 25th, November 2d, the apparent and mean solar days are of equal length. The greatest interval between apparent and mean noon happens on November 2d, on which mean noon is later than apparent noon by 16 minutes and 16 seconds; or, which amounts to the same thing, when the sun's centre transits the meridian on November 2d, the time shown by an uniform clock is 11 hours, 43 minutes, 44 seconds.

58. The ASTRONOMICAL DAY is reckoned from noon to noon, and consists of 24 hours. This is called a *natural* day, being of the same length in all latitudes.

59. The ARTIFICIAL DAY is the time elapsed between the sun's rising and setting, and is variable according to the different latitudes of places.

60. The CIVIL DAY, like the astronomical or natural day, consists of 24 hours, but begins differently in different nations. The ancient Babylonians, Persians, Syrians, and most of the eastern nations, began their day at sun-rising. The ancient Athenians, the Jews, &c. began their day at sun-setting, which custom is followed by the modern Austrians, Bohemians, Silesians, Italians, Chinese, &c. The Arabians begin their day at noon, like the modern astronomers. The ancient Egyptians, Romans, &c. began their day at midnight, and this method is followed by the English, French, Germans, Dutch, Spanish, and Portuguese.

61. A SIDERIAL DAY is the interval of time from the passage of any fixed star over the meridian, till it returns to it again: or, it is the time which the earth takes to revolve once round its axis, and consists of 23 hours, 56 minutes, 4 seconds, of mean solar time.

In elementary books of astronomy and the globes, the learner is generally told that the earth turns on its axis from west to east in 24 hours; but the truth is, that it turns on its axis in 23 hours, 56 minutes, 4 seconds, making about 366 revolutions in 365 days, or a year. The natural day would always consist of 23 hours, 56 minutes, 4 seconds, instead of 24 hours, if the earth had no other motion than that on its axis; but while the earth has revolved eastward once round its axis, it has advanced nearly one degree* eastward in its orbit. To illustrate this, suppose the sun to be upon any particular meridian at 12 o'clock on any day; in 23 hours, 56 minutes, 4 seconds, afterwards, the earth will have performed one entire revolution; but it will at the same time have advanced nearly one degree eastward in its orbit, and consequently that meridian which was opposite to the sun the day before, will be now one degree westward of it; therefore the earth must perform something more than one revolution before the sun appears again on the same meridian; so that the time from the sun's being on the meridian on any day, to its appearance on the same meridian the next day, is 24 hours.

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* The earth goes round the sun in 365¼ days nearly; and the ecliptic, which is the earth's path round the sun, consists of 360 degrees; hence by the rule of

62. A **Solar Year**, or tropical year, is the time the sun takes in passing through the ecliptic, from one tropic, or equinox, till it returns to it again: and consists of 365 days, 5 hours, 48 minutes, 48 seconds.

63. A **Siderial Year** is the time which the sun takes in passing from any fixed star, till he returns to it again, and consists of 365 days, 6 hours, 9 minutes, 12 seconds; the siderial year is therefore 20 minutes, 24 seconds longer than the tropical year, and the sun returns to the equinox every year before he returns to the same point of the heavens; consequently the equinoctial points have a retrogade motion.

64. The **Precession of the Equinoxes**, arises from a slow retrogade motion of the equinoctial points from east to west, contrary to the order of the signs, which is from west to east.

This motion, from the best observations, is about 50¼* seconds in a year, so that it would require 25,791 years† for the equinoctial points to perform an entire revolution westward round the globe.

In the time of Hipparchus, and the oldest astronomers, the equinoctial points were fixed in Aries and Libra; but the signs which were then in conjunction with the sun, when he was in the equinox, are now a whole sign, or 30 degrees eastward of it; so that Aries is now in Taurus, Taurus in Gemini, &c. as may be seen on the celestial globe. Hence also the stars, which rose and set at any particular season of the year, in the time of Hesiod‡, Eudoxus§, Pliny¶, &c. do not answer to the description given by those writers.

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three, 365¼ D: 360 deg.: : 1 D: 59′ 8″ 2, the daily mean motion of the earth in its orbit, or the *apparent* mean motion of the sun in a day. Hence a clock, or chronometer, the index of which performs an exact circuit whilst the earth (or the meridian of an observer) moves over 360° 59′ 8″. 2, is said to be adjusted to mean solar time.

* In *Woodhouse's* Astronomy, the *mean* annual precession is stated to be 50″. 34, and in the new *French* Solar Tables 50′. 1.

† For the circumference of the equator is 360 degrees, and 50¼″: 1 year: : 360°: 25,791 years.

‡ **Hesiod** was a celebrated Grecian poet, born at Ascra in Bœotia, supposed to have flourished in the time of Homer; he was the first who wrote a poem on Agriculture, entitled *The Works and the Days*, in which he introduces the rising and setting of particular stars, &c. Several editions of his work are now extant.

§ **Eudoxus** was a great geometrician and astronomer, from whom Euclid, the geometrician, is said to have borrowed great part of his elements of geometry. Eudoxus was born at Cnidus, a town of Caria, in Asia Minor; he flourished about 370 years before Christ.

¶ **Pliny**, generally called Pliny the Elder, was born at Verona, in Italy; he

65. Positions of the Sphere are three: right, parallel, and oblique.

66. A Right Sphere is that position of the earth where the equinoctial passes through the zenith and the nadir, the poles being in the rational horizon. The inhabitants who have this position of the sphere live at the equator: it is called a right sphere, because the parallels of latitude cut the horizon at right angles. In a right sphere the parallels of latitude are divided into two equal parts by the horizon, and the days and nights are of equal length.

67. A Parallel Sphere is that position the earth has when the rational horizon coincides with the equator, the poles being in the zenith and nadir. The inhabitants who have this position of the sphere, (if there be any such inhabitants) live at the poles; it is called a parallel sphere, because all the parallels of latitude are parallel to the horizon. In a parallel sphere the sun appears above the horizon for six months together, and he is below the horizon for the same length of time.

68. An Oblique Sphere is that position the earth has when the rational horizon cuts the equator obliquely, and hence it derives its name. All inhabitants on the face of the earth, (except those who live exactly at the poles or at the equator,) have this position of the sphere. The days and nights are of unequal lengths, the parallels of latitude being divided into unequal parts by the rational horizon.

69. Climate is a part of the surface of the earth contained between two small circles parallel to the equator, and of such a breadth, that the longest day in the parallel nearest the pole, exceeds the longest day in the parallel of latitude nearest the equator, by half an hour, in the torrid and temperate zones, or by a month in the frigid zones; so that there are 24 climates between the equator and each polar circle, and six climates between each polar circle and its pole.

From the above definition, it appears that all places situated on the same parallel of latitude are in the same climate; but we must not infer from thence that they have the same atmospherical temperature; large tracts of uncultivated lands, sandy deserts, elevated situations, woods, morasses, lakes, &c. have a considerable effect on the atmosphere. For instance, in Canada, in about the latitude of Paris and the south of England, the cold is so excessive, that the greatest rivers are frozen over from December to April, and the snow commonly

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composed a work on natural history in 37 books; it treats of the stars, the heavens, wind, rain, hail, minerals, trees, flowers, plants, birds, fishes, and beasts; besides a geographical description of every place on the globe, &c. &c. Pliny perished by an eruption of Vesuvius, in the 79th year of Christ, from too eager curiosity in observing the phenomenon.

lies from four to six feet deep. The Andes mountains, though part of them are situated under the torrid zone, are at the summit covered with snow, which cools the air in the adjacent country. The heat on the western coast of Africa, after the wind has passed over the sandy desert, is almost suffocating; whilst the same wind having passed over the Atlantic Ocean, is cool and pleasant to the inhabitants of the Caribbean Islands.

I. CLIMATES between the Equator and the Polar Circles.

| *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climates.* | | *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climate.* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D. | M. | H. | M. | D. | M. | | D. | M. | H | M. | D. | M. |
| I | 8 | 34 | 12 | 30 | 8 | 34 | XIII | 59 | 59 | 18 | 30 | 1 | 32 |
| II | 16 | 44 | 13 | — | 8 | 10 | XIV | 61 | 18 | 19 | — | 1 | 19 |
| III | 24 | 12 | 13 | 30 | 7 | 28 | XV | 62 | 26 | 19 | 30 | 1 | 8 |
| IV | 30 | 48 | 14 | — | 6 | 36 | XVI | 63 | 22 | 20 | — | — | 56 |
| V | 36 | 31 | 14 | 30 | 5 | 43 | XVII | 64 | 10 | 20 | 30 | — | 48 |
| VI | 41 | 24 | 15 | — | 4 | 53 | XVIII | 64 | 50 | 21 | — | — | 40 |
| VII | 55 | 32 | 15 | 30 | 4 | 8 | XIX | 65 | 22 | 21 | 30 | — | 32 |
| VIII | 49 | 2 | 16 | — | 3 | 30 | XX | 65 | 48 | 22 | — | — | 26 |
| IX | 51 | 59 | 16 | 30 | 2 | 57 | XXI | 66 | 5 | 22 | 30 | — | 17 |
| X | 54 | 30 | 17 | — | 2 | 31 | XXII | 66 | 21 | 23 | — | — | 16 |
| XI | 56 | 38 | 17 | 30 | 2 | 8 | XXIII | 66 | 29 | 23 | 30 | — | 8 |
| XII | 58 | 27 | 18 | — | 1 | 49 | XXIV | 66 | 32 | 24 | — | — | 3 |

II. CLIMATES between the Polar Circles and the Poles.

| *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climates.* | | *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climates.* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D. | M. | Da. | M. | D. | M. | | D. | M. | Da. | M. | D. | M. |
| XXV | 67 | 18 | 30 or | 1 | — | 46 | XXVIII | 77 | 40 | 120 or | 4 | 4 | 35 |
| XXVI | 69 | 33 | 60 — | 2 | 2 | 15 | XXIX | 82 | 59 | 150 — | 5 | 5 | 19 |
| XXVII | 73 | 5 | 90 — | 3 | 3 | 32 | XXX | 90 | — | 180 — | 6 | 7 | 1 |

The preceding tables may be constructed by the globes, as will be shown in the problems, but not with that exactness given above. Tables of this kind are generally copied from one author into another, without any explanation of the principles on which they are founded.

### *Construction of the first Table.*

In *plate* IV. *figure* IV. HO represents the horizon, ÆQ the equator, ♋ *e* ♋ a parrallel of the sun's greatest declination, NO the elevation of the pole or latitude of the place; the angle *c a b* measured by the arc QO, the complement of the latitude; *a b* is the ascensional difference, or the time the sun rises before 6 o'clock, and *b c* the sun's declination. Hence by Baron Napier's rules, (see *Keith's* Spherical Trigonometry,) *rad.* × *sine a b* = *cotangent a** (*or tangent* NO) × *tangent b c.*

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I. CLIMATES between the EQUATOR and the POLAR CIRCLES.

| *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climates.* | | *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climate.* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D. | M. | H. | M. | D. | M. | | D. | M. | H | M. | D. | M. |
| I | 8 | 34 | 12 | 30 | 8 | 34 | XIII | 59 | 59 | 18 | 30 | 1 | 32 |
| II | 16 | 44 | 13 | — | 8 | 10 | XIV | 61 | 18 | 19 | — | 1 | 19 |
| III | 24 | 12 | 13 | 30 | 7 | 28 | XV | 62 | 26 | 19 | 30 | 1 | 8 |
| IV | 30 | 48 | 14 | — | 6 | 36 | XVI | 63 | 22 | 20 | — | — | 56 |
| V | 36 | 31 | 14 | 30 | 5 | 43 | XVII | 64 | 10 | 20 | 30 | — | 48 |
| VI | 41 | 24 | 15 | — | 4 | 53 | XVIII | 64 | 50 | 21 | — | — | 40 |
| VII | 55 | 32 | 15 | 30 | 4 | 8 | XIX | 65 | 22 | 21 | 30 | — | 32 |
| VIII | 49 | 2 | 16 | — | 3 | 30 | XX | 65 | 48 | 22 | — | — | 26 |
| IX | 51 | 59 | 16 | 30 | 2 | 57 | XXI | 66 | 5 | 22 | 30 | — | 17 |
| X | 54 | 30 | 17 | — | 2 | 31 | XXII | 66 | 21 | 23 | — | — | 16 |
| XI | 56 | 38 | 17 | 30 | 2 | 8 | XXIII | 66 | 29 | 23 | 30 | — | 8 |
| XII | 58 | 27 | 18 | — | 1 | 49 | XXIV | 66 | 32 | 24 | — | — | 3 |

II. CLIMATES between the POLAR CIRCLES and the POLES.

| *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climates.* | | *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climates.* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D. | M. | Da. | M. | D. | M. | | D. | M. | Da. | M. | D. | M. |
| XXV | 67 | 18 | 30 or | 1 | — | 46 | XXVIII | 77 | 40 | 120 or | 4 | 4 | 35 |
| XXVI | 69 | 33 | 60 — | 2 | 2 | 15 | XXIX | 82 | 59 | 150 — | 5 | 5 | 19 |
| XXVII | 73 | 5 | 90 — | 3 | 3 | 32 | XXX | 90 | — | 180 — | 6 | 7 | 1 |

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65. **Positions of the Sphere** are three: right, parallel, and oblique.

66. A **Right Sphere** is that position of the earth where the equinoctial passes through the zenith and the nadir, the poles being in the rational horizon. The inhabitants who have this position of the sphere live at the equator: it is called a right sphere, because the parallels of latitude cut the horizon at right angles. In a right sphere the parallels of latitude are divided into two equal parts by the horizon, and the days and nights are of equal length.

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68. An **Oblique Sphere** is that position the earth has when the rational horizon cuts the equator obliquely, and hence it derives its name. All inhabitants on the face of the earth, (except those who live exactly at the poles or at the equator,) have this position of the sphere. The days and nights are of unequal lengths, the parallels of latitude being divided into unequal parts by the rational horizon.

69. **Climate** is a part of the surface of the earth contained between two small circles parallel to the equator, and of such a breadth, that the longest day in the parallel nearest the pole, exceeds the longest day in the parallel of latitude nearest the equator, by half an hour, in the torrid and temperate zones, or by a month in the frigid zones; so that there are 24 climates between the equator and each polar circle, and six climates between each polar circle and its pole.

From the above definition, it appears that all places situated on the same parallel of latitude are in the same climate; but we must not infer from thence that they have the same atmospherical temperature; large tracts of uncultivated lands, sandy deserts, elevated situations, woods, morasses, lakes, &c. have a considerable effect on the atmosphere. For instance, in Canada, in about the latitude of Paris and the south of England, the cold is so excessive, that the greatest rivers are frozen over from December to April, and the snow commonly

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I. CLIMATES between the EQUATOR and the POLAR CIRCLES.

| *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climates.* | | *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climate.* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D. | M. | H. | M. | D. | M. | | D. | M. | H | M. | D. | M. |
| I | 8 | 34 | 12 | 30 | 8 | 34 | XIII | 59 | 59 | 18 | 30 | 1 | 32 |
| II | 16 | 44 | 13 | — | 8 | 10 | XIV | 61 | 18 | 19 | — | 1 | 19 |
| III | 24 | 12 | 13 | 30 | 7 | 28 | XV | 62 | 26 | 19 | 30 | 1 | 8 |
| IV | 30 | 48 | 14 | — | 6 | 36 | XVI | 63 | 22 | 20 | — | — | 56 |
| V | 36 | 31 | 14 | 30 | 5 | 43 | XVII | 64 | 10 | 20 | 30 | — | 48 |
| VI | 41 | 24 | 15 | — | 4 | 53 | XVIII | 64 | 50 | 21 | — | — | 40 |
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| VIII | 49 | 2 | 16 | — | 3 | 30 | XX | 65 | 48 | 22 | — | — | 26 |
| IX | 51 | 59 | 16 | 30 | 2 | 57 | XXI | 66 | 5 | 22 | 30 | — | 17 |
| X | 54 | 30 | 17 | — | 2 | 31 | XXII | 66 | 21 | 23 | — | — | 16 |
| XI | 56 | 38 | 17 | 30 | 2 | 8 | XXIII | 66 | 29 | 23 | 30 | — | 8 |
| XII | 58 | 27 | 18 | — | 1 | 49 | XXIV | 66 | 32 | 24 | — | — | 3 |

II. CLIMATES between the POLAR CIRCLES and the POLES.

| *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climates.* | | *Climate.* | *Ends in Latitude.* | | *Where the longest Day is.* | | *Breadths of the Climates.* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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viz. Tangent of the sun's greatest declination 23° 28′.
Is to radius, sine of 90 degrees;
*As sine of the sun's ascensional difference,*
*Is to tangent of latitude.*————A general rule.

At the end of the first climate the sun rises $\frac{1}{4}$ before 6; and in every climate, if you take half the length of the longest day, and deduct 6 hours therefrom, the remainder turned into degrees will give the ascensional difference. Hence the ascensional difference, for the first climate, is fifteen minutes of time, equal to 3° 45′; for the second climate 30 minutes = 7° 30′; for the third climate 45 minutes = 11° 15′; for the fourth climate 1 hour = 15°, &c.

| | | | |
|---|---|---|---|
| Tangent of 23° 28′ | 9.63761 | Tangent of 23° 8′ | 9.63761 |
| Is to radius, sine of 90° | 10.00000 | Is to radius, sine of 90° | 10.00000 |
| As sine of 3° 45′. | 8.81560 | As sine of 7° 30′ | 9.11570 |
| Is to tang. lat. 8° 34′ | 9.17799 | Is to tang. lat. 16° 44′ | 9.47809 |

### *Construction of the Second Table.*

The longest day is the 21st of June, when the sun's declination is 23° 28′ north. Count half the length of the day from the 21st June, forward and backward; find the sun's declination answering to those two days in the nautical almanac, or in a table of the sun's declination; add the two declinations together, and divide their sum by 2, substract the quotient from 90 degrees, and the remainder is the latitude. As the sun's declination is variable, it ought to be taken out of the almanac, or tables, for leap year and the three following years, a mean of these declinations, used as above, will give the latitude as correct as the nature of the problem admits of, and in this manner the second table was constructed. Ricciolі, (an Italian astronomer and mathematician, born at Ferrara, in the Pope's dominions, 1598,) in his *Astronomiæ Reformatæ*, published in 1665, makes an allowance for the refraction of the atmosphere in a table of climates. He considers the increase of days to be by half hours, from 12 to 16 hours; by hours, from 16 to 20 hours; by 2 hours, from 20 to 24 hours; and by months in the frigid zones, making the number of the days of each month in the north frigid zone something more than those in the south; but as the refraction of the atmosphere is so extremely variable, that scarcely any two mathematicians agree with respect to the quantity, it is evident that a table of climates, calculated with such an uncertain allowance, can be of no material advantage.

70. A Zone is a portion of the surface of the earth contained between two small circles parallel to the equator, and is similar to the term climate, for pointing out the situations of places on the earth, but less exact; as there are only *five* zones, which have been distinguished by particular names; whereas there are 60 climates.

71. The Torrid Zone extends from the tropic of Cancer to the tropic of Capricorn, and is 46° 56′ broad. This zone was thought by the ancients to be uninhabited, because it is continually exposed to the direct rays of the sun; and such parts of the torrid zone as were known to them were sandy deserts; as, the middle of Africa, Arabia, &c.; and those sandy deserts which extend beyond the left bank of the Indus, toward Agimere.

72. The Two Temperate Zones. The north temperate zone extends from the tropic of Cancer to the arctic circle; and the south temperate zone from the tropic of Capricorn to the antarc-

tic circle. These zones are each 43° 4′ broad, and were called temperate by the ancients, because meeting the sun's rays obliquely, they enjoy a moderate degree of heat.

73. The Two Frigid Zones. The north frigid zone, or rather segment of the sphere, is bounded by the arctic circle. The north pole, which is 23° 28′ from the arctic circle, is situated in the centre of this zone. The south frigid zone is bounded by the antarctic circle, distant 23° 28′ from the south pole, which is situated in the centre of this zone.

74. Amphiscii are the inhabitants of the torrid zone; so called, because their shadows fall north or south at different times of the year; the sun being sometimes to the south of them at noon, and at other times to the north. When the sun is vertical, or in the zenith, which happens twice in the year, the inhabitants have no shadow, and are then called Ascii, or shadowless.

75. Heteroscii is a name given to the inhabitants of the temperate zones, because their shadows at noon fall only one way. Thus, the shadow of an inhabitant of the north temperate zone always falls to the north at noon, because the sun is then due south; and the shadow of an inhabitant of the south temperate zone falls towards the south at noon, because the sun is due north at that time.

76. Periscii are those people who inhabit the frigid zones, so called, because their shadows, during a revolution of the earth on its axis, are directed towards every point of the compass. In the frigid zones the sun does not set during several revolutions of the earth on its axis.

77. Antœci are those who live in the same degree of longitude, and in equal degrees of latitude, but the one in north and the other in south latitude. They have noon at the same time, but contrary seasons of the year; consequently the length of the days to the one, is equal to the length of the nights to the other. Those who live at the equator can have no Antœci.

78. Periœci are those who live in the same latitude, but in opposite longitudes; when it is noon with the one, it is midnight with the other; they have the same length of days, and the same seasons of the year. The inhabitants of the poles can have no Periœci.

79. Antipodes are those inhabitants of the earth who live diametrically opposite to each other, and consequently walk feet to feet; their latitudes, longitudes, seasons of the year, days and nights, are all contrary to each other.

80. The Right Ascension of the sun, or of a star, is that degree of the equinoctial which rises with the sun, or star, in a right

[illegible] equinoctial point Aries eastward [illegible]

[illegible] of a star, is that degree [illegible] the sun or star, in an oblique [illegible] from the point Aries eastward [illegible]

[illegible] the sun or of a star, is that degree of [illegible] the sun or star in an oblique sphere.

[illegible] ASCENSIONAL DIFFERENCE is the [illegible] and oblique ascension, or the difference [illegible] oblique descension, and with respect [illegible] rises before 6 in the spring and summer [illegible] in the autumn and winter.

[illegible] TWILIGHT, is that faint light which [illegible] the sun rises, and after he sets. It is produced [illegible] refracted in their passage through the [illegible] and reflected from the different particles [illegible] twilight is supposed to end in the evening when [illegible] degrees below the horizon, or when stars of the sixth [illegible] smallest that are visible to the naked eye) begin [illegible] the twilight is said to begin in the morning, or it [illegible] when the sun is again within 18 degrees of the horizon. [illegible] twilight is the shortest at the equator, and longest at [illegible] the sun is near two months before he retreats 18 [illegible] the horizon, or to the point where his rays are first [illegible] the atmosphere; and he is only two months more [illegible] at the same parallel of latitude.

[illegible] REFRACTION. The earth is surrounded by a body of air, [illegible] ATMOSPHERE, through which the rays of light come to the [illegible] the heavenly bodies; and since these rays are admit- [illegible] at least through a very *rare medium**, and [illegible] upon the atmosphere, which is a dense medium, they [illegible] the laws of optics, be refracted in lines approaching near- [illegible] perpendicular from the place of the observer (or nearer to [illegible] than they would be were the medium to be removed. [illegible] all the heavenly bodies appear higher than they really are, [illegible] nearer they are to the horizon the greater the refraction, [illegible] between their apparent and true altitudes, will be; at [illegible] refraction is the least. The sun and the moon appear of [illegible] sometimes near the horizon, by reason of refraction;

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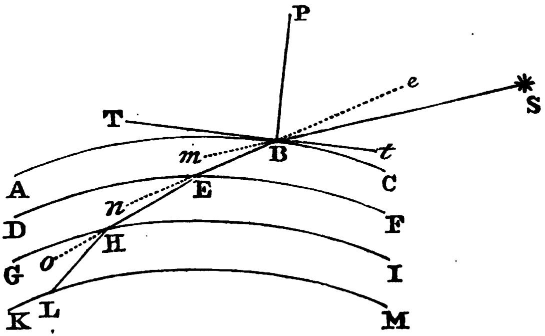
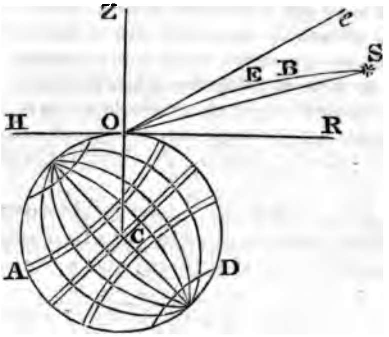
* [illegible] through which a ray of light can penetrate, is called a [illegible] The air near the surface of the earth is more [illegible] than in the higher regions of the atmosphere; and beyond the atmosphere,

for the under side being more refracted than the upper, the perpendicular diameter will be less than the horizontal one, which is not affected by refraction.



It has long been established, by experiment, that a ray of light passing from a rarer to a denser medium, is refracted towards the denser medium. Thus, if ABC be the boundary between two media, of which the lower one is the denser, then a ray of light SB, instead of pursuing its direction SB*m*, is deflected in the direction BE, and a star, instead of appearing at S, would appear at *e*, that is nearer to a perpendicular BP, meeting a tangent T*t* at the point of incidence B. Again, if DEF be a similar boundary, separating the rarer medium contained between ABC and DEF from the denser medium contained between DEF and GHI, the ray of light instead of pursuing its new course BE*n* will be again deflected in the direction EH; and similar effects will be produced if more media and their boundaries be added. Hence, a ray of light, instead of being a continued straight line, is broken into parts BE, EH, HL, inclined to each other at the angles, BEH, EHL, &c. If we suppose these media to be indefinitely increased, and their boundaries to approach each other by spaces extremely small, the parts BE, EH, HL, may be considered as curvilinear, and the course of a ray, instead of being polygonal, will be a curve, concave towards the denser medium. This may be more adequately represented by the following figure.

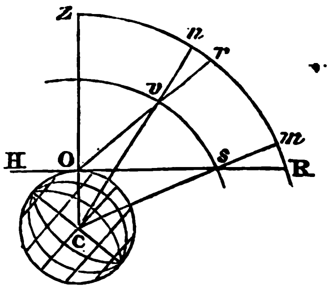


Here the media are no longer parcelled out into different *strata* of variable density, but are considered as one medium of a density continually varying; such is the earth's atmosphere, the most dense at its surface, and decreasing towards the higher regions. A ray of light will consequently, in its passage through the atmosphere, be deflected into a curve concave towards the earth's surface, and will enter a spectator's eye in the direction of a tangent to that curve; a star will, therefore appear in that direction.

Let o be the place of an observer, HOR his horizon, and s a star; AOD a section of the earth, formed by a vertical plane passing through the star at s and the centre (c) of the earth. Here *e* is the apparent place of the star, and s its true place; the angle *e*OR is the apparent altitude of the star, and the angle SOR its true altitude, the angle *e*OS, therefore is the refraction. If the star were at z, the zenith of the observer, its height would suffer no refraction. Refraction depends upon a star's altitude and the heights of the barometer and thermometer; viz. upon the height of the object, and the state of the atmosphere; hence we sometimes are able to see the tops of mountains, towers, or spires of churches, which at other times are invisible, though we stand in the same place. The ancients knew nothing of refraction, the first who composed a table thereof was *Tycho Brahe.* The table now in common use was constructed by *Dr. Bradley**, or from his formula, being the result of many trials, conjectures, and experiments. In the Nautical Almanac for 1822, there is a table of refractions, calculated from an ingenious formula, explained by Dr. Young, in the Philosophical Transactions for 1819.

The sun's meridian altitude on the longest day decreases from the tropic of Cancer to the north pole; and in the torrid zone, when the sun is vertical there is no refraction; hence the refraction is the least in the torrid zone, and greatest at the poles. Varenius, in his geography, speaking of the wintering of the Dutch in Nova Zembla, latitude 76° north, in the year 1596, says they saw the sun in the year 1597 six days sooner than they would have seen him, had there been no refraction.

86. PARALLAX. That part of the heavens in which a planet would appear, if viewed from the surface of the earth, is called its *apparent place;* and the point in which it would be seen at the same instant from the centre of the earth is called its *true place;* the difference is the parallax. A fixed star, on account of its great distance from the earth, has no sensible parallax.



Let c be the centre of the earth, o the place of an observer on its surface whose sensible horizon is HOR, and zenith z. Then if *znrm*R be a portion of a vertical circle in the heavens, and s the real place of any object in the horizon, if cs be joined and produced to *m*, it will show the true place of s; the angle *ms*R or cso is the parallax. Hence the altitudes of the celestial bodies are depressed by parallax, which is the greatest at the horizon, and decreases as the altitude of the object increases; for the angle co*v* is greater than the angle cos, consequently the angle o*v*c is less than the angle osc. At the zenith z the angle o*v*c vanishes, and therefore the parallax ceases.

87. ANGLE OF POSITION between two places on the terrestrial globe, is an angle at the zenith of one of the places; formed by the meridian of that place, and a vertical circle passing through the

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other place, being measured on the horizon from the elevated pole towards the vertical circle.

The ANGLE OF POSITION OF A STAR, is an angle formed by two great circles intersecting each other in the place of the star, the one passing through the pole of the equinoctial, the other through the pole of the ecliptic. This angle may be computed from the obliquity of the ecliptic, and the co-latitude and co-declination of the star; it is used in several astronomical calculations. *M. Lalande* has given a table of the angles of positions of stars in his Astronomy, 2d ed. vol. i. page 488.; and in the *Connaissance des Tems* for 1804, there is a table of the same kind.

88. RHUMBS are the divisions of the horizon into 32 parts, called the points of the compass. The* ancients were acquainted only with the four cardinal points, and the wind was said to blow from that point to which it was nearest.

A Rhumb line geometrically speaking, is a loxodromic or spiral curve, drawn, or supposed to be drawn, upon the earth, so as to cut each meridian at the same angle, called the proper angle of the rhumb. If this line be continued, it will never return into itself so as to form a circle, except it happens to be due east and west, or due north and south; and it can never be a straight line upon any map, except the meridians be parrallel to each other, as in Mercator's and the plane chart. Hence the difficulty of finding the *true* bearing between two places on the terrestrial globe, or on any map but those above mentioned. The bearing found by a quadrant of altitude on a globe, is only the measure of a spherical angle upon the surface of that globe, as defined by the *angle of position*, and not the real bearing or rhumb, as shown by the compass; for, by the compass, if a place A bear due east from a place B, the place B will bear due west from the place A; but this is not the case when measured with a quadrant of altitude.

89. The FIXED STARS are so called because they have usually been observed to keep the same distance with respect to each other. The stars have an apparent motion from east to west, in circles parrallel to the equinoctial, arising from the revolution of the earth on its axis, from west to east; and, on accout of the precession of the equinoxes, their longitudes increase about 50 1-4 seconds in a year; this likewise causes a variation in their declinations and right ascensions: their latitudes are also subject to a small variation.

90. The POETICAL RISING AND SETTING OF THE STARS, so called because they are taken notice of by the ancient poets, who referred the rising and setting of the stars to the sun. THUS, when a star rose with the sun, or set when the sun rose, it was said to rise and set COSMICALLY. When a star rose at sun-setting, or set with the sun, it was said to rise and set ACRONICALLY. When a star first became visible in the morning, after having been so near the sun as to be hid by the splendor of his rays, it was

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* Pliny's Nat. Hist. Lib. II. chap. 47.

said to RISE HELICALLY; and when a star first became invisible in the evening, on account of its nearness to the sun, it was said to SET HELICALLY.

91. A CONSTELLATION is an assemblage of stars on the surface of the celestial globe, circumscribed by the outlines of some assumed figure, as a *ram*, a *dragon*, a *bear*, &c. This division of the stars into constellations is necessary, in order to direct a person to any part of the heavens where a particular star is situated.

The following tables contain all the constellations on the BRITISH GLOBES. The ZODIACAL constellations are 12 in number, the NORTHERN constellations 35, and the SOUTHERN 47, making in the whole 94. By adding together the numbers of stars in the *first* columns of the following tables, the total will be found to be 3457; of this number there are only 19 of the first magnitude, and 422 cannot be seen at London. The largest stars are called stars of the first magnitude. Those of the sixth magnitude are the smallest that can be seen by the naked eye. The figures on the left hand of the tables show the number of stars in each constellation, from *Flamstead's* Catalogue; R denotes right ascension, D declination of the middle of the several constellations, for the ready finding them on the globe. The modern constellations are distinguished from the ancient by an asterisk.

## I. CONSTELLATIONS IN THE ZODIAC.

| Number of Stars. | *Names of the Constellations, and of the principal Stars in each, with their magnitudes.* | R. | D. |
|---|---|---|---|
| 66. | Aries, *The Ram*, Arietis 2, | 30. | 22 N. |
| 141. | Taurus, *The Bull*, Aldebaran 1, the Pleiades, the Hyades, | 65. | 16 N. |
| 85. | Gemini, *The Twins*, Castor 1, Pollux 2, | 111. | 32 N. |
| 83. | Cancer, *The Crab*, Acubene 4, | 128. | 20 N. |
| 95. | Leo, *The Lion*, Regulus or Cor Leonis 1, Deneb 2, | 150. | 15 N. |
| 110. | Virgo, *The Virgin*, Spica Virginis 1, Vendemiatrix 2, | 192. | 5 N. |
| 51. | Libra, *The Balance*, Zubenich Meli 2, | 226. | 8 S. |
| 44. | Scorpio, *The Scorpion*, Antares 1, | 244. | 26 S. |
| 69. | Sagittarius, *The Archer*, | 285. | 35 S. |
| 51. | Capricornus, *The Goat*, | 310. | 20 S. |
| 108. | Aquarius, *The Water Bearer*, Scheat 3, | 335. | 4 S. |
| 113. | Pisces, *The Fishes*, | 5. | 10 N. |

## II. THE NORTHERN CONSTELLATIONS.

| Number of Stars. | Names of the Constellations | R. | D. |
|---|---|---|---|
| 66. | Andromeda, Mirach 2, Almaach 2, | 15. | 35 N. |
| 71. | Aquila, *The Eagle*, with Antinöus, Altair or Atair, 1, | 295. | 8 N. |
| 25. | Asterion et Chara*, vel Canes Venatici, *The Greyhounds*, | 200. | 40 N. |
| 66. | Auriga, *The Charioteer or Waggoner*, Capella 1, | 75. | 45 N. |
| 54. | Böotes, Arcturus 1, Mirach 3, | 212. | 20 N. |
| 58. | Camelopardalus*, *The Camelopard*, | 68. | 70 N. |
| 59. | Caput Medusæ, *The Head of Medusa*, and Perseus, | 44. | 40 N. |
| 55. | Cassiopeia, *The Lady in her Chair*, Schedar 3, | 12. | 60 N. |
| 35. | Cepheus, Alderamin 3, | 338. | 65 N. |
| — | Cerberus, *The Three-headed Dog*, and Hercules, | 271. | 22 N. |
| 43. | Coma Berenices, *Berenice's Hair*, | 185. | 26 N. |
| 3. | Cor Caroli*, *Charles Heart*, | 191. | 39 N. |
| 21. | Corona Borealis, *The Northern Crown*, Alphacca 2, | 235. | 30 N. |
| 81. | Cygnus, *The Swan*, Deneb Adige 1, | 308. | 42 N. |

| Number of Stars. | *Names of the Constellations and of the principal Stars in each, with their magnitudes.* | R. | D. |
|---|---|---|---|
| 18. | Delphinus, *The Dolphin,* | 308. | 15 N. |
| 80. | Draco, *The Dragon,* Rastaben 2 | 270. | 66 N. |
| 10. | Equulus, *The Little Horse,* | 316. | 5 N. |
| 113. | Hercules, *vide Cerberus,* Ras Algethi 3, | 245. | 22 N. |
| 16. | Lacerta*, *The Lizard,* | 336. | 43 N. |
| 53. | Leo Minor*, *The Little Lion,* | 150. | 35 N. |
| 44. | Lynx*, *The Lynx,* | 111. | 50 N. |
| 22. | Lyra, *The Harp,* Vega or Wega 1. | 283. | 38 N. |
| 11. | Mons Mœnalus *The Mountain Mænalus,* | 225. | 5 N. |
| 6. | Musca*, *The Fly,* | 40. | 27 N. |
| 89. | Pegasus, *The Flying Horse,* Markab 2, Scheat 1, | 340. | 14 N. |
|  | Perseus, *vide Caput Medusæ,* Algenib 2, Algol 2, | 46. | 49 N. |
| 18. | Sagitta, *The Arrow,* | 295. | 18 N. |
| 8. | Scutum Sobieski* *Sobieski's Shield,* | 275. | 10 S. |
| 64. | Serpens, *The Serpent,* | 235. | 10 N. |
| 74. | Serpentarius, *The Serpent Bearer,* Ras Alhagus 2, | 260. | 13 N. |
| 7. | Taurus Poniatowski*, *The Bull of Poniatowski,* | 275. | 7 N. |
| 11. | Triangulum, *The Triangle,* | 27. | 32 N. |
| 5. | Triangulum Minus, *The Little Triangle,* | 31. | 29 N. |
| 87. | Ursa Major, *The Great Bear,* Dubhe 1, Alioth 2, Benetnach 2, | 153. | 60 N. |
| 24. | Ursa Minor, *The Little Bear,* Polar Star, or Alrukabah 2, | 235. | 75 N. |
| 37. | Vulpecula et Anser*, *The Fox and Goose,* | 300. | 25 N. |
| 10. | Tarandus*, *The Rein Deer,* | 30. | 75 N. |

To the preceding list of northern constellations, foreign Mathematicians have added Le Messier, Taurus Regalis, Fredericks Ehre, *Frederick's Glory,* Tubus Herschelii Major, *Herschel's Great Telescope.*

### III. THE SOUTHERN CONSTELLATIONS.

|  |  |  |  |
|---|---|---|---|
| 11. | Apus vel Avis Indica*, *The Bird of Paradise,* | 252. | 75 S. |
| 9. | Ara, *The Altar,* | 255. | 55 S. |
| 64. | Argo Navis, *The Ship Argo,* Canopus 1, | 115. | 50 S. |
| 3. | Brandenburgium Sceptrum*, *The Sceptre of Brandenburg,* | 67. | 15 S. |
| 31. | Canis Major, *The Greot Dog,* Sirius 1, | 105. | 20 S. |
| 14. | Canis Minor, *The Little Dog,* Procyon 1, | 110. | 5 N. |
| 35. | Centaurus, *The Centaur,* | 200. | 50 S. |
| 97. | Cetus, *The Whale,* Mencar 2, | 25. | 12 S. |
| 10. | Chamæleon*, *The Cameleon,* | 175. | 78 S. |
| 4. | Circinus*, *The Compasses,* | 222. | 64 S. |
| 10. | Columba Noachi*, *Noah's Dove,* | 85. | 35 S. |
| 12. | Corona Australis, *The Southern Crown,* | 278. | 40 S. |
| 9. | Corvus, *The Crow,* Algorab 3, | 185. | 15 S. |
| 31. | Crater, *The Cup or Goblet,* Alkes 3, | 168. | 15 S. |
| 6. | Crux*, *The Cross,* | 183. | 60 S. |
| 7. | Dorado ot Xiphias*, *The Sword Fish,* | 75. | 62 S. |
| 8. | Equuleus Pictorius*, *The Painter's Easel,* | 84. | 55 S. |
| 84. | Eridanus, *The River Po,* Acherner 1, | 60. | 10 S. |
| 14. | Fornax Chemica*, *The Furnace,* | 42. | 30 S. |
| 13. | Grus*, *The Crane,* | 330. | 45 S. |
| 12. | Horologium*, *The Clock,* | 40. | 60 S. |
| 60. | Hydra, *The Water Serpent,* Cor Hydræ 1, | 139. | 8 S. |
| 10. | Hydrus*, *The Water Snake,* | 28. | 68 S. |
| 12. | Indus*, *The Indian,* | 315. | 55 S. |
| 19. | Lepus, *The Hare,* | 80. | 18 S. |
| 24. | Lupus, *The Wolf,* | 230. | 45 S. |
| 3. | Machina Pneumatica*, *The Air Pump,* | 150. | 32 S. |
| 10. | Microscopium*. *The Microscope,* | 315. | 35 S. |
| 31. | Monoceros*, *The Unicorn,* | 110. | 0 |

| Number of Stars. | *Names of the Constellations, and of the principal Stars in each, with their magnitudes.* | R. | D. |
|---|---|---|---|
| 30. | Mons Mensæ*, *The Table Mountain,* | 76. | 72 S. |
| 4. | Musca Australis, vel Apes*, *The Southern Fly or Bee,* | 185. | 68 S. |
| 12. | Norma vel Quadra Euclidis*, *Euclid's Square,* | 242. | 45 S. |
| 43. | Octans Hadleianus*, *Hadley's Octant,* | 310. | 80 S. |
| 12. | Officina Sculptoria*, *The Sculptors Shop,* | 3. | 38 S. |
| 78. | Orion, Betelgeux 1, Rigel 1, Bellatrix 2, | 80. | 0 |
| 14. | Pavo*, *The Peacock,* | 302. | 68 S. |
| 13. | Phœnix*, | 10. | 50 S. |
| 24. | Piscis Notius, vel Australis, *The Southern Fish,* Fomalhaut 1, | 335. | 30 S. |
| 8. | Piscis Volans*, *The Flying Fish,* | 127. | 68 S. |
| 16. | Praxiteles, vel cela Sculptoria*, *The Engraver's Tools,* | 68. | 40 S. |
| 4. | Pyxis Nautica*, *The Mariner's Compass,* | 130. | 30 S. |
| 10. | Reticulus Rhomboidalis*, *The Rhomboidal Net,* | 62. | 62 S. |
| 12. | Robur Caroli*, *Charle's Oak,* | 159. | 50 S. |
| 41. | Sextans*, *The Sextant,* | 145. | 0 |
| 9. | Telescopium*, *The Telescope,* | 278. | 50 S. |
| 9. | Touchan*, *The American Goose,* | 359. | 66 S. |
| 5. | Triangulum Australis*, *The Southern Triangle,* | 238. | 65 S. |
| — | Xiphias*, *vide Dorado,* | 75. | 62 S. |

Foreign mathematicians have added to the preceding list of southern constellations, Solitaire, *an Indian Bird;* Psalterium Georgianum, *The Georgian Psaltery;* Tubus Herschelii Minor, *Herschel's Less Telescope;* Montgolfier's Balloon; The Press of Guttenberg; and the Cat.

## *Explanation of the different emblematical Figures delineated on the Surface of the Celestial Globe.*

### I. THE CONSTELLATIONS IN THE ZODIAC.

It is conjectured that the figures in the signs of the zodiac are descriptive of the seasons of the year, and that they are Chaldean or Egyptian hieroglyphics, intended to represent some remarkable occurrence in each month. Thus the spring signs were distinguished for the production of those animals which were held in the greatest esteem, viz. the sheep, the black-cattle, and the goats; the latter being the most prolific, were represented by the figure of Gemini.—When the sun enters Cancer, he discontinues his progress towards the north pole, and begins to return back towards the south pole. This retrograde motion was represented by a *Crab,* which is said to go backwards. The heat that usually follows in the next month is represented by the *Lion,* an animal remarkable for its fierceness, and which, at this season, was frequently impelled, through thirst, to leave the sandy desert and make its appearance on the banks of the Nile. The sun entered the 6th sign about the time of harvest, which season was therefore represented by a virgin, or female reaper, with an ear of corn in her hand. When the sun enters *Libra,* the days and nights are equal all over the world, and seem to observe an equilibrium, like a balance.

Autumn, which produces fruits in great abundance, brings with it a variety of diseases; this season is represented by that venomous animal the *Scorpion,* who wounds with a sting in his tail as he recedes. The fall of the leaf was the season for hunting, and the stars which marked the sun's path at this time were represented by a huntsman, or *archer,* with his arrows and weapons of destruction.

The *Goat,* which delights in climbing and ascending some mountain or precipice, is the emblem of the winter solstice, when the sun begins to ascend from the southern tropic, and gradually to increase in height for the ensuing half year.

*Aquarius,* or the Water-bearer, is represented by the figure of a man pouring out water from an urn, an emblem of the dreary and uncomfortable season of winter.

The last of the zodiacal constellations was *Pisces*, or a couple of fishes, tied back to back, representing the fishing-season. The severity of the winter is over, the flocks do not afford sustenance, but the seas and rivers are open, and abound with fish.

The Chaldeans and Egyptians were the original inventors of astronomy; they registered the events in their history, and the mysteries of their religion among the stars by emblematical figures. The Greeks displaced many of the Chaldean constellations, and placed such images as had reference to their own history in their room. The same method was followed by the Romans; hence the accounts given of the signs of the zodiac, and of the constellations, are contradictory and involved in fable.

## II. THE NORTHERN CONSTELLATIONS.

ANDROMEDA is represented on the celestial globe by the figure of a woman almost naked, having her arms extended, and chained by the wrist of her right arm to a rock. She was the daughter of Cepheus, king of Ethiopia, who, in order to preserve his kingdom, was obliged to tie her naked to a rock near Joppa, now Jaffa, in Syria, to be devoured by a sea-monster; but she was rescued by Perseus, in his return from the conquest of the Gorgons, who turned the monster into a rock by showing it the head of Medusa. Andromeda was made a constellation after her death, by Minerva.

ANTINŌUS was a youth of Bithynia, in Asia Minor, a great favourite of the emperor Adrian, who erected a temple to his memory, and placed him among the constellations. Antinöus is generally reckoned a part of the constellation Aquila.

AQUILA is supposed to have been Merops, a king of the island of Cos, one of the Cyclades; who, according to Ovid, was changed into an eagle, and placed among the constellations.

ASTERION ET CHARA, *vel* CANES VENATICI, the two greyhounds, held in a string by Bōotes: they were formed by Hevelius out of the *Stellæ Informes* of the ancient catalogues.

AURIGA is represented on the celestial globe by the figure of a man in a kneeling or sitting posture, with a goat and her kids in her left hand, and a bridle in his right. The Greeks give various accounts of this constellation; some suppose it to be Erichthonius, the fourth king of Athens, and son of Vulcan and Minerva; he was very deformed, and his legs resembled the tail of serpents; he is said to have invented chariots, and the manner of harnessing horses to draw them. Others say that Auriga is Mirtilus, a son of Mercury and Phaetusa; he was charioteer to Œnomaus, king of Pisa, in Elis, and so experienced in riding and the management of horses, that he rendered those of Œnomaus the swiftest in all Greece; his infidelity to his master proved at last fatal to him, but being a son of Mercury, he was made a constellation after his death. But as neither of these fables seem to account for the goat and her kids, it has been supposed that they refer to Amalthæa, daughter of Melissus, king of Crete, who, in conjunction with her sister Melissa, fed Jupiter with goat's milk; it is moreover said that Amalthæa was a goat called Olenia, from its residence at Olenus, a town of Peloponnesus.

BŌOTES is supposed to be Arcas, a son of Jupiter and Calisto; Juno, who was jealous of Jupiter, changed Calisto into a bear; she was near being killed by her son Arcas in hunting. Jupiter, to prevent farther injury from the huntsmen, made Calisto a constellation of heaven, and on the death of Arcas, conferred the same honour on him. Bōotes is represented as a man in a walking posture, grasping in his left hand a club, and having his right hand extended upwards, holding the cord of the two dogs Asterion and Chara, which seem to be barking at the Great Bear; hence Bōotes is sometimes called the bear-driver, and the office assigned him is to drive the two bears round about the pole.

**Camelopardalus** was formed by Hevelius. The Camelopard is remarkably tame and tractable; its natural properties resemble those of the camel, and its body is variegated with spots like the leopard. This animal is found in Ethiopia and other parts of Africa; its neck is about seven feet long, its fore and hind legs from the hoof to the second joint, are nearly of the same length; but from the second joint of the legs to the body, the fore legs are so long in comparison with the hind ones, that the body seems to slope like the the roof of a house.

**Cassiopeia** was the wife of Cepheus, and mother of Andromeda. *See these constellations, as also Cetus.*

**Cepheus** was a king of Ethiopia, and the father of Andromeda by Cassiopeia; Cepheus was one of the Argonauts, who went with Jason to Colchis to fetch the golden fleece.

**Cerberus** was a dog belonging to Pluto, the god of the infernal regions; this dog had fifty heads according to Hesiod, and three according to other mythologists; he was stationed at the entrance of the infernal regions, as a watchful keeper, to prevent the living from entering, and the dead from escaping from their confinement. The last and most dangerous exploint of Hercules, was to drag Cerberus from the infernal regions, and bring him before Eurystheus, king of Argos.

**Coma Berenices** is composed of the unformed stars, between the Lion's Tail and Bŏotes. Berenice was the wife of Evergetes, a surname signifying benefactor: when he went on a dangerous expedition, she vowed to dedicate her hair to the goddess Venus, if he returned in safety. Sometime after the victorious return of Evergetus, the locks which were in the temple of Venus disappeared; and Conon, an astronomer, publicly reported that Jupiter had carried them away, and made them a constellation.

**Cor Caroli**, or Charles's heart, in the neck of Chara, the southernmost of the two dogs held in a string by Bootes, was so denominated by Sir Charles Scarborough, physician to king Charles II. in honour of king Charles I.

**Corona Borealis** is a beautiful crown given by Bacchus, the son of Jupiter, to Ariadne, the daughter of Minos, second king of Crete. Bacchus is said to have married Ariadne after she was basely deserted by Theseus, king of Athens, and after her death the crown which Bacchus had given her was made a constellation.

**Cygnus** is fabled by the Greeks to be the swan under the form of which Jupiter deceived Leda, or Nemesis, the wife of Tyndarus, king of Laconia. Leda was the mother of Pollux and Helena, the most beautiful woman of the age; and also of Castor and Clytemnestra. The two former were deemed the offspring of Jupiter, and the others claimed Tyndarus as their father.

**Delphinus**, the dolphin, was placed among the constellations by Neptune, because, by means of a dolphin, Amphitrite became the wife of Neptune, though she had made a vow of perpetual celibacy.

**Draco.** The Greeks give various accounts of this constellation; by some it is represented as the watchful dragon which guarded the golden apples in the garden of the Hesperides, near mount Atlas, in Africa; and was slain by Hercules: Juno, who presented these apples to Jupiter on the day of their nuptials, took Draco up to Heaven, and made a constellation of it as a reward for its faithful services: others maintain, that in a war with the giants, this dragon was brought into combat, and opposed to Minerva, who seized it in her hands and threw it, twisted as it was, into the heavens round the axis of the earth, before it had time to unwind its contortions.

**Equulus**, the little horse, or *Equi Sectio*, the horse's head, is supposed to be the brother of Pegasus.

**Hercules** is represented on the celestial globe holding a club in his right hand, the three-headed dog Cerberus in his left, and the skin of the Nemæan Lion thrown over his shoulders. Hercules was the son of Jupiter and Alcmena, and reckoned the most famous hero of Antiquity.

**Leo Minor** was formed out of the *Stellæ Informes*, or unformed stars of the ancients, and placed above **Leo** the zodiacal constellation. According to the Greek fables, **Leo** was the celebrated Nemæan lion which had dropped from the moon, but being slain by Hercules, was elevated to the heavens by Jupiter, in commemoration of the dreadful conflict, and in honour of that hero. But this constellation was amongst the Egyptian hieroglyphics, long before the invention of the fables of Hercules. See the Zodiacal Constellations, p. 48. Nemæa was a town of Argolis in Peloponnesus, and was infested by a lion which Hercules slew, and clothed himself in the skin; games were instituted to commemorate this great event.

The **Lynx** was composed by Hevelius out of the unformed stars of the ancients, between Auriga and Ursa Major.

**Lyra**, the lyre or harp, is included in Vultur Cadens. This constellation was at first a tortoise, afterwards a lyre, because the strings of the lyre were originally fixed to the shell of a tortoise: it is asserted that this is the lyre which Apollo or Mercury gave to Orpheus, and with which he descended the infernal regions, in search of his wife Eurydice. Orpheus after death received divine honours, the Muses gave an honourable burial to his remains, and his lyre became one of the constellations.

**Mons Mænalus.** The mountain Mænalus in Arcadia was sacred to the god Pan, and frequented by shepherds; it received its name from Mænalus, a son of Lycaon, king of Arcadia.

**Pegasus**, the winged horse, according to the Greeks, sprung from the blood of the Gorgon Medusa, after Perseus, a son of Jupiter, had cut off her head. Pegasus fixed his residence on mount Helicon in Bœotia, where, by striking the earth with his foot, he produced a fountain called Hippocrene. He became the favourite of the Muses, and being afterwards tamed by Neptune, or Minerva, he was given to Bellerophon to conquer the Chimæra, a hideous monster that continually vomited flames; the fore-parts of its body were those of a lion, the middle was that of a goat, and the hinder-parts were those of a dragon; it had three heads, viz. that of a lion, a goat, and a dragon. After the destruction of this monster, Bellerophon attempted to fly to heaven upon Pegasus, but Jupiter sent an insect which stung the horse, so that he threw down the rider. Bellerophon fell to the earth, and Pegasus continued his flight up to heaven, and was placed by Jupiter among the constellations.

**Perseus** is represented on the globe with a sword in his right hand, the head of Medusa in his left, and wings at his ancles. Perseus was the son of Jupiter and Danäe. Pluto, the god of the infernal regions, lent him his helmet, which had the power of rendering its bearer invisible; Minerva, the goddess of wisdom, furnished him with her buckler, which was as resplendent as glass; and he received from Mercury wings, and a dagger or sword; thus equipped, he cut off the head of Medusa, and from the blood which dropped from it in his passage through the air, sprang an innumerable quantity of serpents, which ever after infested the sandy deserts of Lybia. Medusa was one of the three Gorgons who had the power to turn into stones all those on whom they fixed their eyes; Medusa was the only one subject to mortality: she was celebrated for the beauty of her locks, but having violated the sanctity of the temple of Minerva, that goddess changed her locks into serpents. *See the constellation Andromeda.*

**Sagitta**, the arrow. The Greeks say that this constellation owes its origin to one of the arrows of Hercules, with which he killed the eagle or vulture that perpetually gnawed the liver of Prometheus, who was tied to a rock on Mount Caucasus, by order of Jupiter.

**Scutum Sobieski** was so named by Hevelius, in honour of John Sobieski, king of Poland. Hevelius was a celebrated astronomer, born at Dantzick: his catalogue of fixed stars was entitled *Firmamentum Sobieskianum*, and dedicated to the king of Poland.

**Serpens** is also called *Serpens Ophiuchi*, being grasped by the hands of *Ophiuchus*

**Serpentarius**, *Ophiucus*, or *Æsculapius*, is represented with a large beard, and holding in his two hands a serpent. The serpent was the symbol of medicine, and of the gods who preside over it, as Apollo and Æsculapius, because the ancient physicians used serpents in their prescriptions.

**Taurus Poniatowski** was called so in honour of Count Poniatowski, a Polish officer of extraordinary merit, who saved the life of Charles XII of Sweden, at the battle of Pultowa, a town near the Dnieper, about 150 miles south-east of Kiov; and a second time at the island of Rugen, near the mouth of the river Oder.

**Triangulum.** A triangle is a well known figure in geometry; it was placed in the heavens in honour of the most fertile part of Egypt, being called the delta of the Nile, from its resemblance to the Greek letter of that name △. The invention of geometry is usually ascribed to the Egyptians, and it is asserted that the annual inundations of the Nile which swept away the bounds and land-marks of the estates, gave occasion to it, by obliging the Egyptians to consider the figure and quantity belonging to the several proprietors.

**Ursa Major** is said to be Calisto, an attendant of Diana, the goddess of hunting. Calisto was changed into a bear by Juno.—*See the constellation Böotes.* It is farther stated that the ancients represented Ursa Major and Ursa Minor, each under the form of a wagon, drawn by a team of horses. Ursa Major is well known to the country people at this day, by the title of *Charles's Wain*, or wagon: in some places it is called the plough. There are two remarkable stars in Ursa Major, considered as the hindmost in the square of the wain, called the pointers, because an imaginary line drawn through these stars, and extended upwards, will pass near the pole-star in the tail of the Little Bear.

**Vulpecula et Anser**, the Fox and the Goose, was made by Hevelius out of the unformed stars of the ancients.

## III. THE SOUTHERN CONSTELLATIONS.

**Ara** is supposed to be the altar on which the gods swore before their combat with the giants.

**Argo Navis** is said to be the ship Argo, which carried Jason and the Argonauts to Colchis to fetch the golden fleece.

**Canis Major**, the Great Dog, according to the Greek fables, is one of Orion's hounds; (*See Canis Minor;*) but the Egyptians, who carefully watched the rising of this constellation, and by it judged of the swelling of the Nile, called the bright star Sirius the centinel and watch of the year; and according to their hieroglyphical manner of writing, represented it under the figure of a dog. The Egyptians called the Nile *Siris*, and hence is derived the name of their deity *Osiris*.

**Canis Minor**, the Little Dog, according to the Greek fables, is one of Orion's hounds; but the Egyptians were most probably the inventors of this constellation, and as it rises before the dog-star, which at a particular season was so much dreaded, as it is properly represented as a little watchful creature, giving notice of the other's approach; hence the Latins have called it Antecanis, the star before the dog.

**Centaurus.** The Centauri were a people of Thessaly, half men and half horses. The Thessalians were celebrated for their skill in taming horses, and their appearance on horseback was so uncommon a sight to the neighbouring states, that at a distance they imagined the man and horse to be one animal: when the Spaniards landed in America, and appeared on horseback, the Mexicans had the same ideas. This constellation is by some supposed to represent Chiron the Centaur, tutor of Achilles, Æsculapius, Hercules, &c.; but as Sagittarius is likewise a Centaur, others have contended that Chiron is represented by Sagittarius.

**Cetus**, the whale, is pretended by the Greeks to be the sea-monster which Neptune, brother to Juno, sent to devour Andromeda; because her mother, Cassiopeia, had boasted herself to be fairer than Juno and the Nereides.

**Corvus**, the crow, was, according to the Greek fables, made a constellation by Apollo: this god being jealous of Coronis, (the daughter of Phlegyas and mother of Æsculapius,) sent a crow to watch her behaviour; the bird, perched on a tree, perceived her criminal partiality to Ischys, the Thessalian, and acquainted Apollo with her conduct.

**Crux, Crusero** or **Crosier**. There are four stars in this constellation forming a cross, by which mariners sailing in the southern hemisphere readily find the situation of the Antarctic pole.

**Eridanus**, the river Po, called by Virgil the king of rivers, was placed in the heavens for receiving Phæton, whom Jupiter struck with thunder-bolts when the earth was threatened with a general conflagration, through the ignorance of Phæton, who had presumed to be able to guide the chariot of the sun. The Po is sometimes called Orion's river.

**Hydra** is the water serpent, which, according to poetic fable, infested the Lake Lerna in Peloponnesus: this monster had a great number of heads, and as soon as one was cut off, another grew in its stead; it was killed by Hercules. The general opinion is, that this Hydra was only a multitude of serpents which infested the marshes of Lerna.

**Lepus**, the hare, according to the Greek fables, was placed near Orion, as being one of the animals which he hunted.

**Microscopium**, the microscope, is an optical instrument composed of lenses or mirrors, so arranged as to render very minute objects clear and distinct.

**Monoceros**, the unicorn, was added by Hevelius, and composed of stars which the ancients had not comprised within the outlines of the other constellations.

**Orion** is represented on the globe by the figure of a man with a sword in his belt, a club in his right hand, and the skin of a lion in his left; he is said by some authors to be the son of Neptune and Euryale, a famous huntress; he possessed the disposition of his mother, became the greatest hunter in the world, and boasted that there was not an animal on the earth which he could not conquer. Others say, that Jupiter, Neptune, and Mercury, as they travelled over Bœotia, met with great hospitality from Hyrieus, a peasant of the country, who was ignorant of their dignity and character. When Hyrieus had discovered that they were gods, he welcomed them by the voluntary sacrifice of an ox. Pleased with his piety, the gods promised to grant him whatever he required, and the old man, who had lately lost his wife, and to whom he made a promise never to marry again, desired them, that as he was childless, they would give him a son without obliging him to break his promise. The gods consented, and Orion was produced from the hide of the ox.

**Piscis Australis**, the southern fish, is supposed by the Greeks to be Venus, who transformed herself into a fish, to escape from the terrible giant Typhon.

**Robur Caroli**, or Charles's Oak, was so called by Dr. Halley, in memory of the tree in which Charles II. saved himself from his pursuers after the battle of Worcester. Dr. Halley went to St. Helena, in the year 1676, to take a catalogue of such stars as do not rise above the horizon of London.

**Sextans**, the sextant, a mathematical instrument well known to mariners, was formed by Hevelius from the *Stellæ Informes* of the ancients.

92. **Galaxy, via lactea**, or *Milky-way*, is a whitish luminous tract which seems to encompass the heavens, like a girdle, of a considerable though unequal breadth, varying from about 4 to 20 degrees. It is composed of an infinite number of small stars, which by their joint light occasion that confused whiteness which we perceive in a clear night when the moon does not shine very bright. The Milky-way may be traced on the celestial globe,

beginning at Cygnus, through Cepheus, Cassiopeia, Perseus, Auriga, Orion's club, the feet of Gemini, part of Monoceros, Argo Navis, Robur Caroli, Crux, the feet of the Centaur, Circinus, Quadra Euclidis, and Ara; here it is divided into two parts; the eastern branch passes through the tail of Scorpio, the bow of Sagittarius, Scutum Sobieski, the feet of Antinöus, Aquila, Sagitta, and Vulpecula; the western branch passes through the upper part of the tail of Scorpio, the right side of Serpentarius, Taurus Poniatowski, the Goose, and the neck of Cygnus, and meets the aforesaid branch in the body of Cygnus.

93. **Nebulous**, or *cloudy*, is a term applied to certain fixed stars smaller than those of the sixth magnitude, which only show a dim hazy light like little specks or clouds. In Præsepe, in the breast of Cancer, are reckoned 36 little stars; F. le Compte adds, that there are 40 such stars in the Pleiades, and 2500 in the whole Constellation of Orion. It may be further remarked, that the Milky-way is a continued assemblage of Nebulæ.

94. **Bayer's Characters.** John Bayer, of Augsburg, in Swabia, published in 1603, an excellent work, entitled *Uranometria*, being a complete atlas of all the constellations, with the useful invention of denoting the stars in every constellation by the letters of the Greek and Roman Alphabets; setting the first Greek letter α to the principal star in each constellation, β to the second in magnitude, γ to the third, and so on, and when the Greek alphabet was finished, he began with *a*, *b*, *c*, &c. of the Roman. This useful method of describing the stars has been adopted by all succeeding astronomers, who have further enlarged it by adding the numbers 1, 2, 3, &c. in the same regular succession, when any constellation contains more stars than can be marked by the two alphabets. The figures are, however, sometimes placed above the Greek letter, especially where double stars occur; for though many stars may appear single to the naked eye, yet when viewed through a telescope of considerable magnifying power, they appear double, triple, &c. Thus, in Dr. Zach's Tabulæ Motuum Solis, we meet with *f* Tauri, β Tauri, γ Tauri, δ Tauri, $\delta_2$ Tauri, &c.

As the Greek letters so frequently occur in catologues of the stars and on the celestial globes, the Greek alphabet is here introduced for the use of those who are unacquainted with the letters. The capitals are seldom used in the catalogues of stars, but are here given for the sake of regularity.

### THE GREEK ALPHABET.

| | | *Name.* | *Sound.* |
|---|---|---|---|
| Α | α | Alpha | a |
| Β | β ϐ | Beta | b |
| Γ | γ Γ | Gamma | g |
| Δ | δ | Delta | d |
| Ε | ε | Epsilon | e *short* |
| Ζ | ζ ζ | Zeta | z |
| Η | η | Eta | e *long* |
| Θ | ϑ θ | Theta | th |
| Ι | ι | Iota | i |
| Κ | ϰ | Kappa | k |
| Λ | λ | Lambda | l |
| Μ | μ | Mu | m |
| Ν | ν | Nu | n |
| Ξ | ξ | Xi | x |
| Ο | ο | Omicron | o *short* |
| Π | π ϖ | Pi | p |
| Ρ | ϱ ρ | Rho | r |
| Σ | σ ς | Sigma | s |
| Τ | τ ⁊ | Tau | t |
| Υ | υ | Upsilon | u |
| Φ | φ | Phi | ph |
| Χ | χ | Chi | ch |
| Ψ | ψ | Psi | ps |
| Ω | ω | Omega | o *long* |

95. **Planets** are opaque bodies, similar to our earth, which move round the sun in certain periods of time. They shine not by their own light, but by the reflection of the light which they receive from the sun. The planets are distinguished into primary and secondary.

96. The **Primary Planets** regard the sun as their centre of motion. There are 11 Primary Planets, distinguished by the following characters and names, viz. ☿ Mercury, ♀ Venus, ⊕ the Earth, ♂ Mars, ⚶ Vesta, ⚵ Juno, ⚳ Ceres, ⚴ Pallas, ♃ Jupiter, ♄ Saturn, and ♅ the Georgium Sidus.

97. The **Secondary Planets**, satellites, or moons, regard the primary planets as their centres of motion: thus the moon revolves round the earth, the satellites of Jupiter move round Jupiter, &c. There are 18 secondary planets. The earth has *one* satellite, Jupiter *four*, Saturn *seven*, and the Georgium Sidus *six*.

98. The **Orbit** of a planet is the imaginary path it describes round the sun. The earth's orbit is in the plane of the ecliptic.

99. Nodes are the two opposite points where the orbit of a planet seems to intersect the ecliptic. That where the planet appears to ascend from the south to the north side of the ecliptic, is called the ascending or north node, and is marked thus ☊ ; and the opposite point where the planet appears to descend from the north to the south, is called the descending or south node, and is marked ☋.

100. Aspect of the stars or planets is their situation with respect to each other. There are five aspects, viz. ☌ *Conjunction*, when they are in the same sign and degree ; ✱ *Sextile*, when they are two signs, or a sixth part of a circle, distant ; □ *Quartile*, when they are three signs, or a fourth part of a circle, from each other ; △ *Trine*, when they are four signs, or a third part of a circle, from each other ; ☍ *Opposition*, when they are six signs, or half a circle, from each other.

The conjunction and opposition (particularly of the moon) are called the *Syzygies ;* and the quartile aspect, the *Quadratures*.

101. Direct. A planet's motion is said to be direct, when it appears (to a spectator on the earth) to go forward in the zodiac, according to the order of the signs.

102. Stationary. A planet is said to be stationary, when (to an observer on the earth), it appears for some time in the same point of the heavens.

103. Retrograde. A planet is said to retrograde, when it apparently goes backward, or contrary to the order of the signs.

104. Digit, the twelfth part of the sun or moon's apparent diameter.

105. Disc, the face of the sun or moon, such as they appear to a spectator on the earth ; for though the sun and moon be really spherical bodies, they appear to be circular planes.

106. Geocentric latitudes and longitudes of the planets are their latitudes and longitudes, as seen from the earth.

107. Heliocentric latitudes and longitudes of the planets are their latitudes and longitudes, as they would appear to a spectator situated in the sun.

108. Apogee, or Apogæum, is that point in the orbit of a planet, the moon, &c. which is farthest from the earth.

109. Perigee, or Perigæum, is that point in the orbit of a planet, the moon, &c. which is nearest to the earth.

110. Aphelion, or Aphelium, is that point in the orbit of the earth, or of any other planet, which is farthest from the sun. This point is called the higher Apsis.

111. Perihelion, or Perihelium, is that point in the orbit of the earth, or of any other planet, which is nearest to the sun. This point is called the lower Apsis.

112. Line of the Apsides is a straight line joining the higher and lower apsis of a planet; viz. a line joining the Aphelium and Perihelium.

113. Eccentricity of the orbit of any planet is the distance between the sun and the centre of the planet's orbit.

114. Occultation is the obscuration or hiding from our sight any star or planet, by the interposition of the body of the moon, or of some other planet.

115. Transit is the apparent passage of any planet over the face of the sun, or over the face of another planet. Mercury and Venus, in their transits over the sun's disc, appear like dark specks.

116. Eclipse of the Sun is an occultation of part of the face of the sun, occasioned by an interposition of the moon between the earth and the sun; consequently all eclipses of the sun happen at the time of new moon.

117. Eclipse of the Moon is a privation of the light of the moon, occasioned by an interposition of the earth between the sun and the moon; consequently all eclipses of the moon happen at full moon.

118. Elongation of a planet is the angle formed by two lines drawn from the earth, the one to the sun, and the other to the planet.*

119. Diurnal Arc is the arc described by the sun, moon, or stars, from their rising to their setting.—The sun's semi-diurnal arc is the arc described in half the length of the day.

120. Nocturnal Arc is the arc described by the sun, moon, or stars, from their setting to their rising.

121. Aberration is an apparent motion of the celestial bodies, occasioned by the earth's annual motion in its orbit, combined with the progressive motion of light.

To illustrate this definition,—If light be supposed to have a progressive motion, the position of a telescope through which a star is viewed must be different from that which it would have been, if light had been instantaneous, and therefore the situation of a star *measured* in the heavens, will be different from its *true* situation. Let $*$ represent the situation of a fixed star, A B the direction of the earth's motion, $*$ B the direction of a particle of light, entering the axis *mo* of a telescope at *o*, and moving through *o* B whilst the earth moves from *m* to B, then if the telescope be kept parallel to itself, the light will descend in the axis.

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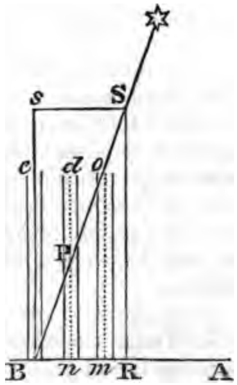
* This and some of the preceding definitions are given to illustrate the 38th and 39th pages of White's Ephemeris, called *Speculum Phænomenorum*. The words *elong. max.* signify the greatest elongation of a planet. In *Plate* II. *Fig.* 2. E represents the Earth, V Venus, and S the Sun. The elongation is the angle VES, measured by the arc VS.

For, let the axis *nd*, B*e* continue parallel to *mo*, then if each motion be considered as uniform, (that of the spectator occasioned by the earth's rotation, being disregarded, because it is so small as to produce no effect,) the spaces described in the same time will retain the same ratio; now *m*B and *o*B being described in the same time, and because *m*B : *o*B : : *mn* : *o*P, it follows that *mn* and *o*P are also described in the same portion of time, and therefore when the telescope is in the situation *nd* the particle of light will be at P in the telescope, and this being the case in every moment of its descent, the situation of the star, measured by the telescope at B is *s*, and the angle $*$ B*s* is the *aberration*. Hence it appears, that if we take BS : BR : : the velocity of light : the velocity of the earth, and complete the parallelogram BRS*s*, the *aberration* will be equal to the angle BSR or SB*s*; S will be the *true* place of the star, and *s* the place measured by the instrument, or its situation as seen by the naked eye.



122. CENTRIPETAL FORCE is that force with which a moving body is perpetually urged towards the centre, and made to revolve in a curve instead of proceeding in a straight line, for all motion is naturally rectilinear.—Centripetal force, attraction, and gravitation, are terms of the same import.

123. Centrifugal force is that force with which a body revolving about a centre, or about another body, endeavours to recede from the curve which it describes. This force is the consequence of that law of motion, by which a body uninfluenced by any external force, necessarily describes a straight line. When a body is compelled to describe a curve line, it is, according to this law, disposed at every instant of the description to leave the curve, and proceed in the direction of the tangent. When a body describes the circumference of a circle, by virtue of a centripetal force directed towards the centre of the circle, the centrifugal force of the body is directly opposed to the centripetal force, and is equal to it in quantity. By the diurnal motion of the earth on its axis, every particle of the earth not situated in the axis describes a circle, and by its natural disposition to move in a straight line, would recede from a circle in the direction of the tangent, unless it were retained by the force of gravity. In this case, the velocities of the particles are proportional to their distances from the axis, and the centrifugal forces of the particles are also proportional to the same distances.

Sir Isaac Newton has demonstrated, (Princip. Prop. XIX. Book III.) that "the "centrifugal force of bodies at the equator, is to the centrifugal force with which "bodies recede from the earth, in the latitude of Paris, in the duplicate ratio of the "radius to the co-sine of the latitude.—And, that the centripetal power in the lati- "tude of Paris, is to the centrifugal force at the equator as 289 is to 1."

## GEOGRAPHICAL THEOREMS.

1. The latitude of any place is equal to the elevation of the polar star (nearly) above the horizon; and the elevation of the equator above the horizon, is equal to the complement of the latitude, or what the latitude wants of 90 degrees.
2. All places lying under the equinoctial, or on the equator, have no latitude, and all places situated on the first meridian have no longitude; consequently that particular point on the globe where the first meridian intersects the equator, has neither latitude nor longitude.
3. The latitudes of places increase as their distances from the equator increase. The greatest latitude a place can have is 90 degrees.
4. The longitudes of places increase as their distances from the first meridian increase, reckoned on the equator. The greatest longitude a place can have is 180 degrees, being half the circumference of the globe at that place; hence no two places can be at a greater distance from each other than 180 degrees.
5. The sensible horizon varies as we travel from one place to another, and its semi-diameter is affected by refraction.
6. All countries upon the face of the earth, in respect to time, equally enjoy the light of the sun, and are equally deprived of the benefit of it; that is, every inhabitant of the earth has the sun above his horizon for six months, and below his horizon for the same length of time.*

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* This, though nearly true, is not accurately so. The refraction in high latitudes is very considerable, (see definition 85th,) and near the poles the sun will be seen for several days before he comes above the horizon; and he will, for the same reason, be seen for several days after he has descended below the horizon.—The inhabitants of the poles (if any) enjoy a very large degree of twilight, the sun being nearly two months before he retreats 18 degrees below the horizon, or to the point where his rays are first admitted into the atmosphere, and he is only two months more before he arrives at the same parallel of latitude; and particularly near the north-pole, the light of the moon is greatly increased by the reflection of the snow, and the brightness of the Aurora Borealis; the sun is likewise about *seven days* longer in passing through the northern, than through the southern signs; that is, from the vernal equinox, which happens on the 21st of March, to the autumnal equinox, which falls on the 23d of September, being the summer half-year to the inhabitants of north latitude, is 186 days, the winter half-year is therefore only 179 days. The inhabitants near the north-pole have consequently more light in the course of a year, than any other inhabitants on the surface of the globe.

7. In all places of the earth, except exactly under the poles, the days and nights are of an equal length, (viz. 12 hours each,) when the sun has no declination, that is, on the 21st of March, and on the 23d of September.

8. In all places situated on the equator, the days and nights are always equal, notwithstanding the alteration of the sun's declination from north to south, or from south to north.

9. In all places, except those upon the equator, or at the two poles, the days and nights are never equal, but when the sun enters the signs of *Aries* and *Libra,* viz. on the 21st of March, and on the 23d of September.

10. In all places lying under the same parallel of latitude, the days and nights, at any particular time, are always equal to each other.

11. The increase of the longest days from the equator northward or southward, does not bear any certain ratio to the increase of latitude; if the longest days increase equally, the latitude increase unequally. This is evident from the table of climates.

12. To all places in the torrid zone, the morning and evening twilight are the shortest; to all places in the frigid zones the longest; and to all places in the temperate zones, a medium between the other two.

13. To all places lying within the torrid zone, the sun is vertical twice a year; to those under each tropic, once; but to those in the temperate and frigid zones, it is never vertical.

14. At all places in the frigid zones, the sun appears every year without setting for a certain number of days, and disappears for nearly the same length of time; and the nearer the place is to the pole, the longer the sun continues without setting; viz. the length of the longest days and nights increase the nearer the place is to the pole.

15. Between the end of the longest day, and the beginning of the longest night, in the frigid zone, and between the end of the longest night, and the beginning of the longest day, the sun rises and sets as at other places on the earth.

16. At all places situated under the arctic or antarctic circles, the sun when he has 23° 28' declination, appears for 24 hours without setting; but rises and sets at all other times of the year.

17. At all places between the equator and the north pole, the longest day and the shortest night are when the sun has (23° 28') the greatest north declination; and the shortest day and longest night are when the sun has the greatest south declination.

18. At all places between the equator and the south-pole, the

the greatest south declination; and the shortest day and longest night are when the sun has the greatest north declination.

19. At all places situated on the equator, the shadow at noon of an object, placed perpendicular to the horizon, falls towards the north for one half of the year, and towards the south the other half.

20. The nearer any place is to the torrid zone, the shorter the meridian shadow of an object will be. When the sun's altitude is 45 degrees, the shadow of any perpendicular object is equal to its height.

21. The farther any place (situated in the temperate or torrid zones) is from the equator, the greater the rising and setting amplitude of the sun will be.

22. All places situated under the same meridian, so far as the globe is enlightened, have noon at the same time.

23. If a ship set out from any port, and sail round the earth eastward to the same port again, the people in that ship, in reckoning their time, will gain one complete day at their return, or count one day more than those who reside at the same port. If they sail westward they will lose one day, or reckon one day less. To illustrate this, suppose the person who travels westward should keep pace with the sun, it is evident he would have continual day, or it would be the *same* day to him during his tour round the earth; but the people who remained at the place he departed from have had night in the same time, consequently they reckon a day more than he does.

24. Hence, if two ships should set out at the same time, from any port, and sail round the globe, the one eastward and the other westward, so as to meet at the same port on any day whatever, they will differ two days in reckoning their time at their return. If they sail twice round the earth, they will differ four days; if thrice, six, &c.

25. But, if two ships should set out at the same time from any port and sail round the globe, northward or southward, so as to meet at the same port on any day whatever, they will not differ a minute in reckoning their time, nor from those who reside at the port.

## Chapter II.

### *Of the General Properties of Matter and the Laws of Motion.*

1. Matter is a substance which, by its different modifications, becomes the object of our five senses; viz. whatever we can see, hear, feel, taste, or smell, must be considered as matter, being the constituent parts of the universe.

2. The properties of matter are extension, figure, solidity, motion, divisibility, gravity, and vis inertiæ. These properties, which Sir Isaac Newton observes* are the foundation of all philosophy, extend to the minutest particles of matter.

3. Extension, when considered as a property of matter, has length, breadth, and thickness.

4. Figure is the boundary of extension; for every finite extension is terminated by, or comprehended under, some figure.

5. Solidity is that property of matter by which it fills space; or, by which any portion of matter excludes every other portion from that space which it occupies. This is sometimes defined the impenetrability of matter.

6. Motion. Though matter of itself has no ability to move, yet as all bodies, upon which we can make suitable experiments, have a capacity of being transferred from one place to another, we infer that motion is a quality belonging to all matter.

7. Divisibility of matter signifies a capacity of being separated into parts, either actually or mentally. That matter is thus divisible, we are convinced by daily experience, but how far the division can be actually carried on is not easily seen. The parts of a body may be so far divided as not to be sensible to the sight; and by the help of microscopes we discover myriads of organized bodies totally unknown before such instruments were invented. A grain of leaf gold will cover fifty square inches of surface†, and contains two millions of visible parts; but the gold which covers the silver wire, used in making gold lace, is spread over a surface twelve times as great. From such considerations as these, we are led to conclude, that the division of matter is carried on to a degree of minuteness far exceeding the bounds of our faculties.

Mathematicians have shown that a line may be indefinitely divided, as follows,

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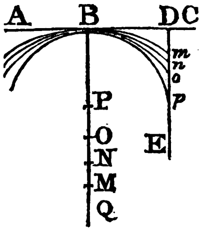
* Newton's Princip. Book III.—The third rule of reasoning in philosophy.



Draw any line AC, and another BM perpendicular to it, of an unlimited length towards Q; and from any point D, in AC, draw DE, parallel to BM. Take any number of points, P, O, N, M, in BQ; then from P as a centre, and the distance PB, describe the arc B*p*, and in the same manner with O, N, M, as centres, the distances OB, NB, and MB describe the arcs B*o*, B*n*, B*m*. Now it is evident the farther the centre is taken from B, the nearer the arcs will approach to D, and the line ED will be divided into parts, each smaller than the preceding one, and since the line BM may be extended to an indefinite distance beyond Q, the line ED, may be indefinitely diminished, yet it can never be reduced to nothing, because an arc of a circle can never coincide with a straight line BC, hence it follows that ED may be diminished *ad infinitum*.

8. Gravity is that force by which a body endeavours to descend towards the centre of the earth. By this power of attraction in the earth, all bodies on every part of its surface are prevented from leaving it altogether, and people move round it in all directions, without any danger of falling from it.—By the influence of attraction, bodies, or the constituent parts of bodies, accede or have a tendency to accede to each other, without any sensible material impulse, and this principle is universally disseminated through the universe, extending to every particle of matter.

9. Vis Inertiæ is that innate force of matter by which it resists any change. We cannot move the least particle of matter without some exertion, and if one portion of matter be added to another, the inertia of the whole is increased; also if any part be removed, the inertia is diminished. Hence, the vis inertiæ of any body is proportional to its weight.

10. Absolute and relative motion. A body is said to be in absolute motion, when its situation is changed with respect to some other body or bodies at rest; and to be relatively in motion, when compared with other bodies which are likewise in motion.

When a body always passes over equal parts of space in equal successive portions of time, its motion is said to be *uniform.*

When the successive portions of space, described in equal times, continually increase, the motion is said to be *accelerated;* and if the successive portions of space continually decrease, the motion is said to be *retarded.* Also, the motion is said to be *uniformly* accelerated or retarded, when the increments or decrements of the spaces, described in equal successive portions of time, are always equal.

11. The VELOCITY of a body, or the rate of its motion, is measured by the space uniformly described in a given time.

12. FORCE. Whatever changes, or tends to change, the state of rest or motion of a body, is called *force.* If a force act but for a moment, it is called the force of percussion or impulse; if it act constantly, it is called an accelerative force; if constantly and equally, it is called an uniform accelerative force.

## GENERAL LAWS OF MOTION.

Law I. "*Every body perseveres in its state of rest, or uniform mo-*
"*tion in a straight line, unless it is compelled to change that state*
"*by forces impressed thereon..*"—Newton's Princip. Book I.*

Thus when a body A is positively at rest, if no external force put it in motion, it will always continue at rest. But if any impulse be given to it in the direction A B, unless some obstacle, or new force, stop or retard its motion, it will continue to move on uniformly, for ever, in the same direction AB.—Hence any projectile, as a ball shot from a cannon, an arrow from a bow, a stone cast from a sling, &c. would not deviate from its first direction, or tend to the earth, but would continue in a straight line with an uniform motion, if the action of gravity and the resistance of the air did not alter and retard its motion.

Law II. "*The alteration of motion, or the motion generated or de-*
"*stroyed, in any body, is proportioned to the force applied; and*
"*is made in the direction of that straight line in which the force*
"*acts.*"—Newton's Princip. Book I.

Thus, if any motion be generated by a given force, a double motion will be produced by a double force, a triple motion by a triple force, &c.—and considering motion as an effect, it will always be found that a body receives its motion in the same direction with the cause that acts upon it.—If the causes of motion be various, and in different directions; the body acted upon must take an oblique or compound direction. Hence a curvilinear motion must arise from the continued action of a force which has not a direction coincident with or opposite to that of the moving body.

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* This and the two following are generally termed *Newton's* three laws of motion; but that he was not the first inventor of them is evident, since they are in *Des Cartes's Principia Philosophiæ*, Part II. pages 38, 39, and 40, which work was [redacted]

Law III. "*To every action there is always opposed an equal reaction; or, the mutual actions of two bodies upon each other are always equal, and directed to contrary points.*"—Newton's Princip. Book I.

If we endeavour to raise a weight by means of a lever, we shall find the lever press the hands with the same force which we exert upon it to raise the weight. Or if we press one scale of a balance, in order to raise a weight in the other scale, the pressure against the finger will be equal to that force with which the other scale endeavours to descend.

When a cannon is fired, the impelling force of the powder acts equally on the breech of the cannon and on the ball, so that if the cannon, with its carriage, and the ball were of equal weight, the carriage would recoil with the same velocity as that with which the ball issues out of the cannon. But the heavier any body is, the less will its velocity be, provided the force which communicates the motion continues the same. Therefore, so many times as the cannon and carriage are heavier than the ball, just so many times will the velocity of the cannon be less than that of the ball.

### COMPOUND MOTION.

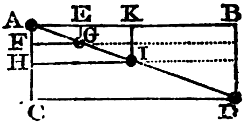
1. *If two forces act at the same time on any body, and in the same direction, the body will move quicker than it would by being acted upon by only one of the forces.*

2. *If a body be acted upon by two equal forces, in exactly opposite directions, it will not be moved from its situation.*

3. *If a body be acted upon by two unequal forces, in exactly contrary directions, it will move in the direction of the greater force.*

4. *If a body be acted upon by two forces, neither in the same nor opposite directions, it will not follow either of the forces, but move in a line between them.*

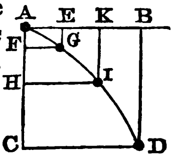
The first three of the preceding articles may be considered as axioms, being self-evident; the fourth may be thus elucidated: Let a force be applied to a body at A, in the direction AB, which would cause it to move uniformly from A to B in a given period of time; and, at the same instant, let another force be applied in the direction AC, such as would cause the body to move from A to C in the



same time which the first force would cause it to move from A to B; by the joint action of these forces, the body will describe the diagonal AD of a parallelogram* with an uniform motion, in the same time in which it would describe one of the sides AB or AC by one of the forces alone.

For, suppose a tube equal in length to AB (in which a small ball can move freely from A to B) to be moved parrallel to itself from A to C, describing with its two extremities the lines AC and BD, so that the ball may move in the tube from A to B in the same time that the tube has descended to CD; it is evident, that when the tube AB coincides with the line CD, the ball will be at the extremity D of the line, and that it has arrived there in the same time it would have described either of the sides AB or AC. The ball will likewise describe the straight line AD, for by assuming several similar parallelograms AEGF, AKIH, &c. it will appear, that while the ball has moved from A to E the tube will have descended from A to F, consequently the ball will be at G; and while the ball has moved from A to K, the tube will have descended from A to H, and the ball will be at I. Now AGID is a straight line; for smaller parallelograms that are similar to the whole, and similarly situated are about the same diagonal.†

5. *If a body, by an uniform motion, describe one side of a parallelogram, in the same time that it would describe the adjacent side by an accelerative force; this body, by the joint action of these forces, would describe a curve, terminating in the opposite angle of the parallelogram.*



Let ABDC be a parallelogram, and suppose the body A to be carried through AB by an uniform force in the same time that it would be carried through AC by an accelerative force, then by the joint action of these forces, the body would describe a curve AGID. For, by the preceding illustration, if the spaces AE, EK, and KB, be proportional to each other, the spaces AF, FH, and HC, will be in the same proportion, and the line AGID will be a straight line when the body is acted upon by uniform forces; but in this example the force in the direction AB being uniform, would cause the body to move over equal spaces AE, EL, and KB, in equal portions of time; while the accelerative force in the direction AC, would cause the body to describe spaces AF, FH, and HC, increasing in magnitude in equal successive portions of time; hence the parallelograms AEGF, AKIH, &c. are not about the same diagonal*, therefore AGID is not a straight line, but a curve. 12 $^{11}_{4}$

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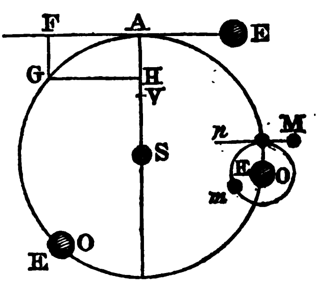
* A parallelogram is a four-sided figure, having its opposite sides parallel, and consequently equal. EUCLID, 34 *of* I.

† EUCLID, 26 *of* VI.

6. *The curvilinear motions of all the planets arise from the uniform projectile forces of bodies in straight lines, and the universal power of attraction which draws them off from these lines.*



If the body E be projected along the straight line EAF, in free space where it meets with no resistance, and is not drawn aside by any other force, it will (by the first law of motion) go on forever in the same direction, and with the same velocity. For, the force which moves it from E to A in a given time, will carry it from A to F in a successive and equal portion of time, and so on; there being nothing either to obstruct or alter its motion. But, if, when the projectile force has carried the body to A, another body as S, begins to attract it, with a power duly adjusted and perpendicular to its motion at A, it will be drawn from the straight line EAF, and revolve about S in the circle† AGOOA. When the body E arrives at O, or any other part of its orbit, if the small body M, within the sphere of E's attraction, be projected, as in the straight line M *n*, with a force perpendicular to the attraction of E, it will go round the body E, in the orbit *m*, and accompany E in its whole course round the body S. Here S may represent the sun, E the earth, and M the moon.

If the earth at A be attracted towards the sun at S, so as to fall from A to H by the force of gravity alone, in the same time which the projectile force singly would have carried it from A to F; by the combined action of these forces it will describe the curve AG; and if the velocity with which E is projected from A, be such as it would have acquired by falling from A to V (the half of AS) by the force of gravity alone‡, it will revolve round S in a circle.

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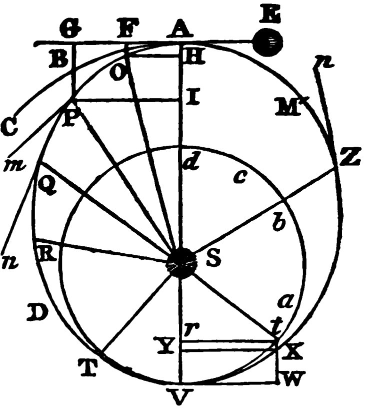
* EUCLID, 24 *of* VI.

† If any body revolve round another in a circle, the revolving body must be projected with a velocity equal to that which it would have acquired by falling through half the radius of the circle, towards the attracting body. *Emerson's Cent. Forces*, Prop. ii.

‡ A body, by the force of gravity alone, falls 16 1-12 feet in the first second of time, and acquires a velocity which will carry it uniformly through 32 1-6 feet in each succeeding second. This is proved experimentally by writers on mechanics.

*7. If one body revolve round another, (as the earth round the sun,) so as to vary its distance from the centre of motion, the projectile and centripetal forces must each be variable, and the path of the revolving body will differ from a circle.*[*]



Thus, if while a projectile force would carry a planet from A to F, the sun's attraction at S would bring it from A to H, the gravitating power would be too great for the projectile force; the planet, therefore, instead of proceeding in the circle ABC (as in the preceding article) would describe the curve AO, and approach nearer to the sun; SO being less than SA. Now, as the centripetal force, or gravitating power always increases as the square of the planet's distance from the sun diminishes[†], when the planet arrives at O the centripetal force will be increased, which will likewise increase the velocity of the planet, and accelerate its motion from O to V; so as to cause it to describe the arcs OP, QR, RD, DT, TV, successively increasing in magnitude, in equal portions of time. The motion of the planet being thus accelerated, it gains such a centrifugal force, or tendency to fly off at V, in the line VW, as overcomes the sun's attraction; this centrifugal or projectile force being too great to allow the planet to approach nearer the sun than it is at V, or even to move round the sun in the circle *t a b c d*, &c., it flies off in the curve XZMA, with a velocity decreasing as gradually from V to A, as if it had returned through the arcs VT, TD, DR, &c. to A, with the same velocity which it passed through these arcs in its motion from A towards V. At A the planet will have acquired the same velocity as it had at first, and thus by the centrifugal and centripetal forces it will continue to move round S.

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[*] A body may revolve in a circle by means of a variable centripetal force, and with a variable velocity, but the centre of force in such cases cannot be co-incident with the centre of the circle: the law of force to make a body describe the circumference of a circle with a variable velocity, about a centre of force situated in any point of the circle, or in the circumference of the circle, or even without the circumference, is determined by Newton, in the Seventh Proposition of the First Book of the Principia.

[†] Newton's Princip. Book III. Prop. ii.

Two very natural questions may here be asked; *viz.* why the action of gravity, if it be too great for the projectile force at o, does not draw the planet to the sun at s? and why the projectile force at v, if it be too great for the centripetal force, or gravity, at the same point, does not carry the planet farther and farther from the sun, till it is beyond the power of his attraction?

*First.* If the projectile force at A were such as to carry the planet from A to G, double the distance, in the same time that it was carried from A to F, it would require four* times as much gravity to retain it in its orbit, *viz.* it must fall through AI in the time that the projectile force would carry it from A to G, otherwise it would not describe the curve AOP. But an increase of gravity gives the planet an increase of velocity, and an increase of velocity increases the projectile force; therefore, the tendency of the planet to fly off from the curve in a tangent P *m*, is greater at P than at o, and greater at Q than at P, and so on; hence, while the gravitating power increases, the projectile power increases, so that the planet cannot be drawn to the sun.

*Secondly.* The projectile force is the greatest at, or near, the point v, and the gravitating power is likewise the greatest at that point. For if AS be double of VS, the centripetal force at V will be four times as great as at A, being as the square of the distance from the sun. If the projectile force at V be double of what it was at A, the space VW, which is the double of AF, will be described in the same time that AF was described, and the planet will be at X in that time. Now, if the action of gravity had been an exact counterbalance for the projectile force during the time mentioned, the planet would have been at *t* instead of X, and it would describe the circle *t*, *a*, *b*, *c*, *&c.;* but the projectile force being too powerful for the centripetal force, the planet recedes from the sun at s, and ascends in the curve XZM, &c. Yet, it cannot fly off in a tangent in its ascent, because its velocity is retarded, and consequently its projectile force is diminished, by the action of gravity. Thus, when the planet arrives at z, its tendency to fly off in a tangent, z *n*, is just as much retarded, by the action of gravity, as its motions was accelerated thereby at Q, therefore it must be retained in its orbit.†

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* Ferguson's Astronomy, Art. 153.

† Many persons are at a loss to conceive in what manner the alternative access and recess of the earth to and from the sun can be reconciled with the known law of centripetal force, which increases as the earth approaches the sun, and decreases as the earth recedes from the sun: thus, the action of the sun on the earth at its greatest distance is the least, and yet it is able to draw the earth from the circular orbit passing through the aphelion, and having the sun in the centre: and when the earth is nearest to the sun, and the centripetal force of the greatest

## CHAPTER II.

### Of the Figure of the Earth, and its Magnitude.

The figure of the earth is composed of land and water, is nearly spherical: the proof of this assertion will be the principal object of this chapter. The ancients held various opinions respecting the figure of the earth: some imagined it to be cylindrical, or in the form of a drum; but the general opinion was that it was a vast extended plane, and that the horizon was the utmost limits of the earth, and the ocean the bounds of the horizon. These opinions were held in the infancy of astronomy; and, in the early ages of Christianity, some of the Fathers went so far as to pronounce it heretical for any person to declare that there was such a thing as the antipodes. But by the industry of succeeding ages, when astronomy and navigation were brought to a tolerable degree of perfection, and when it was observed that the moon was frequently eclipsed by the shadow of the earth, and that such shadow always appeared circular on the disc or face of the moon, in whatever position the shadow was projected, it necessarily followed that the earth, which cast the shadow, must be spherical: since nothing but a sphere, when turned in every position with respect to a luminous body, can cast a circular shadow: likewise

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[illegible], the force is not sufficient to retain the earth at the perihelion distance in a circular orbit, having the sun in the centre of the circle, but allows it to recede from the sun, and ascend towards the aphelion.

When the earth, or a planet, describes an elliptical orbit about the sun situated in one of the foci, the moving body endeavours by its vis inertiae to leave the orbit at every instant, and proceed in the direction of the tangent. To prevent this happening, a certain force directed towards the sun, must be continually applied to the body to produce a continual deflection of the body from the tangent into the curvilinear path. This force at every point must depend on the curvature of the orbit, estimated in the direction of the distance to the sun or radius vector, and on the corresponding velocity of the moving body, with respect to the velocity which a body must have to describe an orbit about a centre of force in free space; it is demonstrated by Newton in his Principia, Corollary I. to Prop. I. that the velocity is every where inversely proportional to the perpendicular let fall on the tangent from the centre of force. In this manner we learn that the velocity of the body depends on the position of the body, and is a function of the radius vector, the form of the function depending on the nature of the orbit. This velocity or function of the distance being denoted by $v$, the central force must increase or decrease as $v$ increases or decreases, when the curvature is the same, the force being proportional to $v^2$, as is fully proved by Newton, and many subsequent writers.

Again, when the curvature is greater, the force must be greater when the velocity is the same, because in the same time the body must be drawn farther from the tangent, in the ratio of the curvature, that is reciprocally as the chord of curvature passing through the centre of force. This chord of curvature, which we may all calculations of eclipses, and of the places of the planets, are made upon supposition that the earth is a sphere, and they all answer to the true times, when accurately calculated. When an eclipse of the moon happens, it is observed sooner by those who live eastward than by those who live westward; and, by frequent experience, astronomers have determined that, for every fifteen degrees difference of longitude, an eclipse begins so many hours sooner in the easternmost place, or later in the westernmost. If the earth were a plane, eclipses would happen at the same time in all places, nor could one part of the world be deprived of the light of the sun while another part enjoyed the benefit of it. The voyages of the circumnavigators sufficiently prove that the earth is round from west to east. The first who attempted to circumnavigate the globe was Magellan, a Portuguese, who sailed from Seville in Spain on the 10th of August, 1519; he did not live to return, but his ship arrived at St. Lucar, near Seville, on the 7th of September, 1522, without altering its direction, except to the north or south, as compelled by the winds, or intervening land. Since this period, the circumnavigation of the globe has been

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denote by $p$, is also a function of the radius vector, and is known for any given curve. Now the force directed to the focus, in which the sun is placed, being directly as $v^2$, and inversely as $p$, is every where proportional to $\frac{v}{p}$, which is the proper measure of the central force, and will in every case be assignable in terms of the radius vector $r$. From this reasoning it follows that whatever be the nature of the curve, and the situation of the centre of force in the plane of the curve, there is at every point of the curve an assignable force which will cause a body to describe the curve.

At the extremities of the transverse axis of the elliptic orbit, the curvature is the same, so that if $v$ and $v'$ be the greater and less velocities at the perihelion and aphelion, the two forces are $\frac{v^2}{p}$ and $\frac{v'^2}{p}$, which because $p$ is common, are in the ratio of $v^2$ to $v'^2$. Now let $r$ and $r'$ be the perihelion and aphelion distances, which are evidently the perpendiculars from the centre of force on the tangents; and therefore by the general rule of Newton for velocities, we have $v : v' :: r' : r$, and therefore $v^2 : v'^2 :: 'r^2 : r^2$; but we have just shown that if $f$ and $f'$ denote the forces at the perihelion and aphelion, we have $v^2 : v'^2 :: f : f'$, consequently,

$$f : f' :: r'^2 : r^2,$$
$$\text{or } f : f' :: \frac{1}{r^2} : \frac{1}{r'^2};$$

that is, the forces at the perihelion and aphelion are inversely, as the squares of the distances. It is evident from this investigation, that the inequality of the forces at the ends of the greater axis, arises entirely from the difference in the velocities at those points. If the velocities were equal, the central forces would also be equal: and if it can be shown that the velocity in the perihelion is greater than that in the aphelion, it follows that the central force in the former point must be greater than that in the latter.

performed at different times by Sir Francis Drake, Lord Anson, Captain Cook, &c. The voyages of the circumnavigators have been frequently adduced by writers on geography and the globes, to prove that the earth is a sphere; but when we reflect that all the circumnavigators sailed westward round the globe, (and not northward and southward round it,) they might have performed the same voyages had the earth been in the form of a drum or cylinder: but the earth cannot be in the form of a cylinder, for if it were, then the difference of longitude between any two places would be equal to the meridional distance between the same places, and on a Mercator's chart, which is contrary to observation.—Again, if a ship sail in any part of the world, and upon any course whatever, on her departure from the coast, all high towers or mountains gradually disappear, and persons on shore may see the masts of the ship after the hull is hid by the convexity of the water, (*see Figure* III. *Plate* I.)—If a vessel sail northward, in north latitude, the people on board may observe the polar star gradually to increase in altitude the farther they go: they may likewise observe new stars continually emerging above the horizon which were before imperceptible; and at the same time those stars which appear southward will continue to diminish in altitude till they become invisible. The contrary phenomena will happen if the vessel sail southward, hence the earth is spherical from north to south, and it has already been shown that it is spherical from east to west.

The arguments already adduced clearly prove the rotundity of the earth, though common experience shows us that it is not strictly a geometrical sphere; for its surface is diversified with mountains and valleys: but these irregularities no more hinder the earth from being reckoned spherical, considering its magnitude, than the roughness of an orange hinders it from being esteemed round.*

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* Our largest globes are in general 18 inches in diameter, and the diameter of the earth is about 7920 miles; also the height of Chimboraço, the highest mountain of the Andes is nearly 4 miles. Now to find on a globe of 9 inches radius, an elevation corresponding to Chimboraço with respect to the earth of 3960 miles in radius,

$$\text{say as } 3960 : 4 :: 9 : \frac{4 \times 9}{3960} = \frac{1}{110},$$

and therefore an elevation of the $\frac{1}{110}$th part of an inch on the surface of a globe 18 inches in diameter, corresponds to the altitude of Chimboraço on the surface of the earth.

The highest point of the Himalaya mountains to the north of Hindostan, surveyed by Capt. Blake, and deduced from his observations by Mr. Colebrake, is 28015 feet above the level of the sea.

*Edinburgh Philosophical Journal*, Vol. V. p. 408.

When philosophical and mathematical knowledge arrived at a still greater degree of perfection, there seemed to be a very sufficient reason for the philosophers of the last age to consider the earth not truly spherical, but in the form of a spheroid.* This notion first arose from observations on pendulum clocks,† which being fitted to beat seconds in the latitudes of Paris and London, were found to move slower as they approached the equator, and at, or near the equator, they were obliged to be shortened about $\frac{1}{8}$ of an inch to agree with the times of the stars passing the meridian. This difference appearing to Huygens‡ and Sir Isaac Newton, to be a much greater quantity than could arise from the alteration by heat only, they separately discovered that the earth was flatted at the poles.§ By the revolution of the earth on its axis, (admitting it to be a sphere) the centrifugal force at the equator would be greater than the centrifugal force in the latitude of London or Paris, because a larger circle is described by the equator, in the same time; but as the centrifugal force (or tendency which a body has to recede from the centre) increases, the action of gravity necessarily diminishes: and where the action of gravity is less, the vibrations of pendulums of equal lengths become slower: hence, supposing the earth to be a sphere, we have two causes why a pendulum should move slower at the equator than at London or Paris, *viz.* the action of heat, which dilates all metals, and the diminution of gravity. But these two causes combined would not, according to Sir Isaac Newton, produce so great a difference as $\frac{1}{6}$ of an inch in the length of a pendulum; he therefore supposed the earth to assume the same figure that a homogeneous fluid would acquire by revolving on an axis, *viz.* the figure of an oblate spheroid, and found that the "diameter of the earth at the equator, is to its diameter from pole to pole, as 230 to 229."* Notwithstanding the deductions of Sir Isaac Newton, on the strictest mathematical principles, many of the philosophers in France, the principal of whom was Cassini†, asserted that the

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* A spheroid is a figure formed by the revolution of an ellipsis about its axis, and an ellipsis is a curve-lined figure in geometry, formed by cutting a cone or cylinder obliquely; but its nature will be more clearly comprehended, by the learner, from the following description.

Let TR (in *Plate* IV. *Figure* V.) be the transverse diameter, or longer axis of the ellipsis, and CO the conjugate diameter, or shorter axis. With the distance TD or DR in your compasses, and C as a centre, describe the arc Ff, the points F, f, will be the two foci of the ellipsis. Take a thread of the length of the transverse axis TR, and fasten its ends with pins in F and f, then stretch the thread FIf and it will reach to I in the curve; then by moving a pencil round with the thread, and keeping it always stretched, it will trace out the ellipsis TCRO. If this ellipsis be made to revolve on its longer axis TR, it will generate an *oblong spheroid* or *Cassini's* figure of the earth; but if it be supposed to revolve on its shorter axis CO, it will form an *oblate spheroid*, or Sir Isaac Newton's figure of the earth. The orbits or paths of all the planets are ellipses, and the sun is situated in one of the *foci* of the earth's orbit, as will be observed farther on. The points F, f, are called foci, or burning points; because if a ray of light issuing from the point F meet the curve in the point I, it will be reflected back into the focus f. For lines drawn from the two foci of an ellipsis to any point in the curve, make equal angles with a tangent to the curve at that point; and by the laws of optics the angle of incidence is equal to the angle of reflection. *Robertson's* Conic Sections, Book III. Scholium to Prop. ix.

† Philosophical Transactions, No. 386.

‡ A celebrated mathematician born at the Hague in Holland, in 1629.

§ Supposing the earth to be an uniformly dense spheroid, which retains its figure by the equilibrium of its gravity and centrifugal force, the length of a simple pendulum vibrating seconds on the equator, is to the length of one vibrating in the same time at the pole, as the axis of the earth to its equatorial diameter; and the increase of length in any latitude above the length at the equator, is as the square of the sine of the latitude, as was first demonstrated by Sir Isaac Newton, and afterwards by other authors. But the figure of the earth, as given by Newton, was derived from the improbable hypothesis of uniform density, and therefore cannot be safely employed in determining by calculation the length of a seconds pendulum in different latitudes. A different method has been adopted by philosophers, which consists in

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deducing the measure of gravity at every point of the earth's surface, from a select number of observations made at different points of the meridian.

According to this method, if the gravity at the equator be denoted by unity, that at the pole will be expressed by 1.005515; and in any latitude $\lambda$ the gravity will be measured by $1 + 005515 \sin{}^2\lambda$.

Thus, in latitude 30° we have $\lambda = 30°$, $\sin. \lambda = \frac{1}{2}$, and $\sin. {}^2\lambda = \frac{1}{4}$, whence $1 + 005515 \sin. {}^2\lambda = 1.001379$.

In latitude 45°, we have $\sin. {}^2\lambda = \frac{1}{2}$, and thus $1 + 005515 \sin. {}^2\lambda = 1.002757$.

In general, if the length of a seconds pendulum at the equator be denoted by $p$, and if $\pi$ be the length of any latitude $\lambda$, we have for determining $\pi$ the following equation:

$$\pi = p\,(1 + 005515 \sin. {}^2\lambda)$$

See on this subject the transactions of the *Am. Phil. Soc.* Vol. I. *New Series*, published in 1818.

* The ratio of 229 to 230, which Newton obtained, for that of the axis of the earth to its equatorial diameter, was deduced from the supposition of uniform density in the earth. It is necessary in determining this figure, to have recourse to methods which are not liable to such uncertainty: by these it is known that the ratio of the axis of the earth to the diameter of the equator, is nearly that of 319 to 320; that the semi-axis is nearly 3951.09 E. miles.
The equatorial semi-diameter - 3963.48
The difference of which is - 12.39
And the mean semi-diameter is - 3959.35
The earth being taken as a sphere, the mean semi-diameter is the radius of the sphere. If a sphere of 18 inches diameter were compressed towards the poles and elevated towards the equator, so as to become similar in figure to the earth, the difference of the semi-diameter would be nearly $\frac{9}{319} = \frac{1}{35}$th part of an inch, which is too small a quantity to be introduced in the construction of such bodies intended to exhibit a representation of the earth.

† Son of the celebrated Italian astronomer; he was born at Paris in 1677.

earth was an oblong spheroid, the polar diameter being the longer: and as these different opinions were supposed to retard the general progress of science in France, the king resolved that the affair should be determined by actual admeasurement at his own expense. Accordingly, about the year 1735, two companies of the most able mathematicians of the nation were appointed; the one to measure the degree of a meridian as near to the equator as possible, and the other company to perform a like operation as near the pole as could be conveniently attempted. The results of these admeasurements contradicted the assertions of Cassini, and of J. Bernouilli, (a celebrated mathematician of Basil in Switzerland, who warmly espoused his cause,) and confirmed the calculations of Sir Isaac Newton. In the year 1756, the Royal Academy of Sciences of Paris appointed eight astronomers to measure the length of a degree between Paris and Amiens: the result of their admeasurement gave 57069 toises for the length of a degree.

The utility of finding the length of a degree in order to determine the magnitude and figure of the earth, may be rendered familiar to the learner thus: suppose I find the latitude of London to be 51½° north, and travel due north till I find the latitude of a place to be 52½° north, I shall then have travelled a degree, and the distance between the two places, accurately measured, will be the length of a degree: now if the earth be a correct sphere, the length of a degree on a meridian, or a great circle, will be equal all over the world, after proper allowances are made for elevated ground, &c.: the length of a degree multiplied by 360 will give the circumference of the earth, and hence its diameter, &c. will be easily found: but if the earth be any other figure than that of a sphere, the length of a degree on the same meridian will be different in different latitudes, and if the figure of the earth resemble an oblate spheroid, the lengths of a degree will increase as the latitudes increase. The English translation of Maupertuis's figure of the earth, concludes with these words: (*see page* 163 *of the work*:) "*The degree of the meridian which cuts the polar circle being longer than the degree of a meridian in* France, *the earth is a spheroid flatted towards the poles.*" For, the longer a degree is, the greater must be the circle of which it is a part; and the greater the circle is, the less is its curvature.

The first person who measured the length of a degree with any appearance of accuracy, was Mr. Richard Norwood: by measuring the distance between London and York, he found the length of a degree to be 367196 English feet, or 69½ English miles; hence, supposing the earth to be a sphere, its circumference will be 25020 miles, and its diameter 7964[*] miles; but if the length of a degree at a medium, be 57069 toises, the circumference of the earth will be 24873 English miles, its diameter 7917 miles, and the length of a degree $69\frac{1}{10}$ miles.[†]

CONCLUSION. Notwithstanding all the admeasurements that have hitherto been made, it has never been demonstrated, in a satisfactory manner, that the earth is strictly a spheroid; indeed, from observations made in different parts of the earth, it appears that its figure is by no means that of a regular spheroid, nor that of any other known regular mathematical figure, and the only certain conclusion that can be drawn from the works of the several gentlemen employed to measure the earth, is, that *the earth is something more flat at the poles than at the equator*. The course of a ship, considering the earth a spheroid, is so near to what it would be on a sphere, that the mariner may safely trust to the rules of *globular* sailing[‡], even though his course and distance were much more certain than it is possible for them to be. For which, and similar reasons, mathematicians content themselves with considering the earth as a sphere in all practical sciences, and hence the artificial globes are made perfectly spherical, as the best representation of the figure of the earth.

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[*] 5280 feet make a mile, therefore 367196 divided by 5280 gives 69½ miles nearly, which multiplied by 360 produces 25020 miles, the circumference of the earth; but the circumference of a circle is to its diameter as 22 to 7, or more nearly as 355 to 113; hence 355 : 113 : : 25020 miles : 7964 miles, the diameter of the earth. Again, 6 French feet make 1 toise, therefore 57069 toises are equal to 342414 French feet; but 107 French feet are equal to 114 English feet, hence 107 F. f. : 114 E. f. : : 342414 F. f. : 364814 English ft. which divided by 5280, the feet in a mile, gives 69.09 miles, the length of a degree by the French admeasurement. Or, 342414 multiplied by 360 produces 123269040 French feet, the circumference of the earth, and 107 : 114 : : 123269040 : 131333369 English feet, equal to 24873.74 miles, the circumference of the earth, and 355 : 113 : :24873.74 : 7917 miles, the diameter of the earth.

[†] The length of a degree in lat. 51° 9′ N. is 364950 feet = 69.12 English miles. Trigonometrical survey of England and Wales, Vol. II. Part II. page 113. Mr. Swanberg, a Swedish mathematician, found the length of a degree to be 57196.159 toises = 365627.782 English feet = 69.247 miles.

[‡] Robertson's Navigation, Book VIII. Art. 143.

# CHAPTER IV.

## *Of the Diurnal and Annual Motion of the Earth.*

The motion of the earth was denied in the early ages of the world, yet as soon as astronomical knowledge began to be more attended to, its motion received the assent of the learned, and of such as dared to think differently from the multitude, or were not apprehensive of ecclesiastical censure. The astronomers of the last and present age have produced such a variety of strong and forcible arguments in favour of the motion of the earth, as must effectually gain the assent of every impartial inquirer.—Among the many reasons for the motion of the earth, it will be sufficient to point out the following:

### 1. *Of the Diurnal Motion of the Earth.*

The earth is a globe of 7920 miles in diameter, (as has been shown in Chap. III.) and by revolving on its axis every 23 h. 56 min. 4 sec. from west to east, it causes an *apparent* diurnal motion of all the heavenly bodies from east to west. We need only look at the sun, or stars, to be convinced, that either the earth, which is no more than a point* when compared with the heavens, revolves on its axis in a certain time, or else the sun, stars, &c. revolve round the earth in nearly the same time. Let us suppose for instance that the sun revolves round the earth in 24 hours, and that the earth has no diurnal motion. Now, it is a known principle in the laws of motion, that if any body revolve round another as its centre, it is necessary that the central body be always in the plane in which the revolving body moves, whatever curve it describes;† therefore if the sun move round the earth in a day, its diurnal path must always describe a circle which will divide the earth into two *equal* hemispheres. But this never happens except on two days of the year, *viz.* at the time of the equinoxes, when the sun rises exactly in the east, and sets exactly in the west. For, from the 21st of March to the 23d of September, the sun rises to the north of the east, and sets to the north of the west; and from the 23d of September to the 21st of March, it rises to the south of the east and sets to the south of the west, and therefore its diurnal path divides the globe into two *unequal* parts; consequently the sun does not move round the earth. To render this more intelligible to a young student, let a pin, of some inches in length, be fixed perpendicularly upon an horizontal plane, and observe the shadow that the top of it describes on any day of the year; this shadow will always be a curve, except at the time of the equinoxes, hence the earth is never in the sun's apparent diurnal orbit but then; for if the top of the pin kept all the time in the plane of the sun's apparent diurnal orbit, the shadow described would be a straight line,* because it would fall in the intersection of two planes;† therefore the sun has no diurnal motion round the earth, consequently the earth has a diurnal motion on its axis.

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* Dr. Keill, Lect. 26.

† Emerson's Astronomy, p. 11.

It is no argument against the earth's diurnal motion, that we do not feel it; a person in the cabin of a ship, on smooth water, cannot perceive the ship's motion when its turns gently and uniformly round;‡ neither does the earth cause bodies to fall from its surface; for all bodies, of whatever matter they are composed, are drawn to the earth by the power of its central attraction;§ which, laying hold of them according to their densities, or quantities of matter, without regard to their magnitudes, constitutes what we call weight.

The phænomena of the *apparent* diurnal motion of the sun may be explained by the motion of the earth; thus, let IFGH (*Plate* I. *fig.* V.) represent the earth, S the sun, and the circle DSBC the apparent concavity of the heavens. Let the earth revolve on its axis from I towards G (viz. from west to east). Suppose a spectator to be at I, the sun, which is at an immense distance, and enlightens half the globe at once, will appear to be rising. As the earth moves round, the spectator is carried towards F, and the sun seems to increase in height; when he has arrived at F, the sun is at the highest. As the earth continues to turn round, the spectator is carried from F towards G, and the altitude of the sun keeps continually diminishing; when he has arrived at G, the sun is setting. During the time the spectator has been carried from I to G, the sun has appeared to move the contrary way. Hence it is evident that while the spectator is carried through the illuminated half of the earth, it is day-light; at the middle point

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* Emerson's Dialling, Prop. II. p. 9th.

† It is demonstrated in EUCLID, Prop. III. Book XI., and in *Keith's* Geometry, Prop. III. Book IX., that if two planes intersect each other, their common section is a straight line.

‡ Ferguson's Astronomy, Art. 119.

§ Newton's Principia, Book III. Prop. vii.

F, it is noon; also while he is carried through the dark hemisphere, it is night; and at H it is midnight. Thus the vicissitude of day and night evidently appears by the rotation of the earth about its axis: what has been said of the sun is equally applicable to the moon, or any star placed at S; therefore all the celestial bodies seem to rise and set by turns, according to their various situations. The spectator at I, F, G, H, will always have his feet towards the centre of the earth, and the sky above his head, whatever position the earth may have; agreeably to the laws of gravitation or attraction. Thus an inhabitant at *a* will be the most powerfully attracted towards his antipodes *b*, because there is the greatest mass of earth under his feet in that direction; for the same reason *b* will be the most attracted towards *a*, *m*, towards *n*, and *n* towards *m*, &c.; hence it appears that every body on the surface of the earth is attracted towards its centre, or rather towards the antipodes of that body, for the *whole earth* is the attracting mass, and not some unknown substance placed in the centre of the earth. There is no such thing as an upper and under side of the earth: suppose *a* to be an inhabitant of Nankin in China, *b* will be an inhabitant of South America near Buenos Ayres, each having the earth under his feet and the sky above his head; also if *n* be an inhabitant a little east of Quito in South America, *on the equator*, *m* will be an inhabitant upon *the equator* in the island of Sumatra, and in the course of 12 hours *n* will have the same position as *m*, by the revolution of the earth.

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## 2. *Of the Annual Motion of the Earth.*

The diurnal revolution of the earth on its axis being proved, the annual motion round the sun will be readily admitted; for, either the earth moves round the sun in a year, or else the sun moves round the earth; now, by the laws of centripetal force, if two bodies revolve about each other, they revolve round their common centre of gravity;* and it is evident, that if the two bodies be of an equal magnitude and density, the centre of gravity will be equi-distant from each body; but, if they be of different masses, the centre of gravity will be nearest to the larger body; if the earth, therefore, remain in the same situation while the sun revolves round it, its mass must be much greater than that of the sun; for it is contrary to the laws of nature for a heavy body to revolve round a light one as its centre of motion: but from observations on the dimensions* and distances of the sun and planets, it appears that the sun so greatly exceeds, not only the earth, but the planets, in mass, that the common centre of gravity of the whole is almost constantly within the body of the sun, so that the sun's motion round the common centre of gravity of the earth and the planets is not perceptible by ordinary observers. Not only the earth, therefore, but the planets, move round the sun.

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* The centre of gravity of two bodies is a point, on which, if they were both supported by a straight line joining their centres, they would rest in equilibrium.

It is also evident that the motion of the earth in its orbit is from west to east, for if the sun be observed to rise with any fixed star, which is near the ecliptic, it will, in the course of a few days, appear to the eastward of that star. And in the period of a year it will arrive at the same star again.

The earth is computed to be 95 millions of miles from the sun,† and performs its revolution round him, described an elliptical orbit or path,‡ in 365 days 5 hours 48 minutes and 48 seconds, from any equinox or solstice to the same again; it travels at the

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* The apparent diameters of the planets are found by a *micrometer* placed in the focus of a telescope, or, the apparent diameter of the sun may be measured by means of the projection of his image into a dark room, through a circular aperture. From these apparent diameters, and the respective distances from the earth, the real diameters of the sun and planets may be determined.

† In *Plate* IV. *Fig*. vi. let o be the centre of the earth, P the place of an observer on its surface, and S the sun or a planet in the heavens: now to an observer at o, the sun would appear at *a*, and to an observer at P it would appear at *b*; the arc *a b*, or the angle *a* S *b* which is equal to the angle PSO, is called the horizontal parallax. Mr. Short, in vol. 52. part ii. of the Philosophical Transactions, has determined the horizontal parallax of the sun to be 8″.65, at its mean distance from the earth. Hence, by trigonometry,

| | |
|---|---|
| Logarithmical sine of 8″.65, or angle PSO - - | 5.6219140 |
| Is to *one* semi-diameter of the earth PO - - | 0.0000000 |
| As radius, sine of 90 degrees, or sine of OPS - - | 10.0000000 |
| Is to 23882.84 semi-diameters - - - - | 4.3780860 |

Now if we take the diameter of the earth 7970 miles, as Mr. Short has done, the semi-diameter 3985 multiplied by 23882.84 gives 95173117 miles, the distance of the earth from the sun: if the diameter of the earth be taken 7964 miles, the distance will be 95101468 miles; if it be taken 7917 miles, (see the chapter of the Figure of the Earth), the distance will be 94540222 miles. In a case of such uncertainty, where a very small error in the parallax will produce an astonishing difference in the conclusion of the process, and where an error in the diameter of the earth will also affect the operation, we may rest content with estimating the distance of the earth from the sun at 95 millions of miles. *Mr. Woodhouse*, in his Astronomy, page 384, calculates the sun's horizontal parallax to be 8″.7017, and at page 284, where he has given the distances of the planets from the sun according to *Laplace*, he states the distance of the earth from the sun to be 93726900 miles.

‡ The idea that the earth moved in an elliptical orbit was first conceived by Kepler, an eminent German astronomer, and demonstrated by Sir Isaac Newton. See the Principia, Book III. Prop. xiii.

rate of upwards of 68,000 miles per hour.[*] Besides this motion, which is common to every inhabitant of the earth, the inhabitants at the equator are carried 1042[†] miles every hour by the diurnal revolution of the earth on its axis, while those in the parallel of London are carried only about 644 miles per hour. The axis of the earth makes an angle of 23° 28′ with a perpendicular to the plane of its orbit, and keeps always the same oblique direction throughout its annual course[‡]; hence it follows, that, during one part of its course, the north pole is turned towards the sun, and, during another part of its course, the south pole is turned towards it in the same proportion; which is the cause of the different seasons, as spring, summer, autumn, and winter. The orbit of the earth being elliptical, the earth must at some times approach nearer to the sun than at others, and will of course take more time in moving through one part of its path than through another. Astronomers have observed that the earth is more rapid in the winter half of its orbit than in the summer, by about seven days; (*see the note to the 6th Geographical Theorem*, p. 59;) but although in the winter we are nearer to the sun than in the summer, yet in that season it seems farthest from us, and the weather is more cold and inclement; the simple account of which phænomenon is, that the sun's rays falling more perpendicularly on us in summer, augment the heat of the weather; so, being transmitted more obliquely on our parallel of latitude during the winter, the cold is increased and rendered more intense. Besides, the days are longer in summer than in winter, on which account the heat of summer is still farther augmented. The heat in the torrid zone does not arise from those parts of the earth being nearer to the sun, but from the rays of the sun falling perpendicular upon, and darting immediately through the atmosphere. It might likewise be expected that, as we are less distant from the sun in the winter than in the summer, it would appear larger; but the difference of situation is so small as to make no sensible alteration in the sun's apparent magnitude.

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[*] The earth's distance from the sun is 95 millions of miles, the mean diameter of its orbit is therefore 190 millions of miles, and the circumference of a circle is three times the diameter and one seventh more; or the circumference is to the diameter as 355 to 113 more nearly; hence 113 : 355 : : 190,000,000 : 596902654, the circumference of the orbit; but this circumference is described in 365 days 5 hours 48 minutes 48 seconds, or 365 days 6 hours nearly, or 8766 hours; hence 8766 h. : 596902654 m. : : 1 h. : 68092 miles *per* hour the inhabitants of the earth are carried by its annual revolution.

[†] These distances are found by multiplying the number of miles contained in a degree in any parallel of latitude by 15; thus the circumference of the earth at the equator is 360° × 69½ m. and in the latitude of London it is equal to 360 × 42.95, and 24 h. : 360° × 69½ : : 1 h. : 1042½ m.; or 1 : 15 × 69½ : : 1 : 1042½ m.

[‡] This is not strictly true, though the variation, called the nutation of the earth's axis, is scarcely perceptible in two or three years. *Keill*, Lect. viii.

The sun is not supposed to be fixed in the centre of the earth's elliptical orbit, but in one of the foci. Let S represent the sun (*Plate* II. *Fig*. 3.) and AGFBDE the elliptical orbit of the earth. Then A is called the Perihelion, or lower apsis, being the earth's nearest distance from the sun; B is called the Aphelion, or higher apsis, being the greatest distance of the earth from the sun, and SC the distance between the sun (in the focus) and the centre, is called the eccentricity of the earth's orbit. If from the centre C there be erected upon the axis AB the perpendicular CE, meeting the orbit in E, and the line SE be drawn, it will represent the mean distance of the earth from the sun, being equal to half the axis AB*, consequently SE is 95 millions of miles.

Though the motion of the earth in its orbit be not uniform, yet it is regulated by a certain immutable law, from which it never deviates; which is, that a line drawn from the centre of the sun to the centre of the earth, being carried about with an angular motion, describes an elliptical area proportional to the time in which that area is described†, *viz*. if the times in which the earth moves from A to E, from E to D, and from D to B, be equal, then the areas, or spaces, ASE, ESD, and DSB, will all be equal. The motion of the earth is sometimes quicker and sometimes slower in moving through equal parts of its orbit; for when the earth is at A (in the winter) the sun attracts it more strongly, and therefore the motion is quicker than any where else; likewise, when it is at B (in the summer) it is least affected by the sun's attraction, and consequently the motion there is slower than in any other part of its orbit, for the power of gravity decreases as the square of the distance increases ‡; besides it is obvious, from the construction of the figure, that, if the space ASE be described in the same time with the space BSD, the arc AE will be greater than the arc BD.

The phænomena of the different seasons of the year will appear plainly from the following observations. Let ABCD (*Plate* III. *Fig*. 1.) represent the plane of the earth's annual orbit, having the sun in the focus F; and let *a b*, an imaginary line passing through the centre of the earth, be perpendicular to this plane; and let the axis NS of the earth make an angle of 23° 28′ with this perpendicular; then if the earth move in the direction A, B, C, D, in such a manner that NS may always remain parallel to itself, and preserve the same angle with *a b*, it will point out the seasons of the year; for, suppose a line to be drawn from the centre of the sun to the centre of the earth, it is evident that the sun will be vertical to that part of the earth which is cut by this line. Now, when the earth is in Libra ♎, the sun will appear to be in Aries ♈, the days and nights will be equal in both hemispheres, and the season a medium between summer and winter; the line dividing the dark and light hemispheres passes through the two poles N and S, and consequently divides all the parallels of latitude, as PR, into two equal parts; hence, the inhabitants of the whole face of the earth have their days and nights equal, viz. twelve hours each. While the earth moves from Libra ♎ to Capricorn ♑, the north pole N will become more and more enlightened, and the south pole S will be gradually involved in darkness, consequently the days in the northern hemisphere will continue to increase in length, and in the southern hemisphere they will decrease in the same proportion, all the parallels of latitude being unequally divided. When the earth has arrived at Capricorn ♑, the sun will appear to be in Cancer ♋, it will be summer to the inhabitants of the northern hemisphere, and winter to those in the southern; the inhabitants at the north pole, and within the arctic circle, will have constant day, and those at the south pole, and within the antarctic circle, will have constant night. While the earth moves from Capricorn ♑ to Aries ♈, the south pole will become more and more enlightened; consequently the days in the southern hemisphere will increase in length, and in the northern hemisphere they will decrease. When the earth has arrived at Aries ♈, the sun will appear to be in Libra ♎, and the days and nights will again be equal all over the surface of the earth. Again, as the earth moves from Aries ♈ towards Cancer ♋, the light will gradually leave the north pole, and proceed to the south; when the earth has arrived at Cancer ♋, it will be summer to the inhabitants in the southern hemisphere, and winter to those in the northern; the inhabitants of the south pole (if any) will have continual day, those at the north pole constant night. Lastly, while the earth moves from Cancer ♋ to Capricorn ♑, the sun will appear to move from Capricorn ♑ to Cancer ♋, and the days in the northern hemisphere will be increasing, while those in the southern will be diminishing in length; and while the earth moves from

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* It is demonstrated by all writers on conic sections, that a line drawn from one end of the conjugate axis of an ellipsis to the focus, is equal to half the transverse axis, *viz*. SE=CB or CA.

† This law was discovered by Kepler, and demonstrated by Sir Isaac Newton. See the Principia, Book III. Prop. xiii.

Capricorn ♑ to Cancer ♋, the sun will appear to move from Cancer ♋ to Capricorn ♑, the days in the northern hemisphere will then be decreasing, and those in the southern hemisphere increasing. In all situations of the earth, the equator will be divided into two equal parts, consequently the days and nights at the equator are always equal. Thus the different seasons are clearly accounted for, by the inclination of the axis of the earth to the plane of its orbit,* combined with the parallel motion of that axis.

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## CHAPTER V.

### *Of the Origin of Springs and Rivers, and of the Saltness of the Sea.*

Various opinions have been held by ancients as well as modern philosophers, respecting the origin of springs and rivers; but the true cause is now pretty well ascertained. It is well known that the heat of the sun draws vast quantities of vapour from the sea, which, being carried by the wind to all parts of the globe, and being converted by the cold into rain and dew, falls down upon the earth; part of it runs down into the lower places, forming rivulets; part serves for the purposes of vegetation, and the rest descends into hollow caverns within the earth, which breaking out by the sides of the hills forms little springs; many of these springs running into the valleys increase the brooks or rivulets, and several of these meeting together make a river.

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* In addition to these observations, the author farther illustrates the seasons of the year by an orrery; and sometimes by a brass wire supported on two stands of different heights, corresponding to the diameter of the wire circle, and the obliquity of the ecliptic, as in Ferguson's Astronomy, chap. x. But as this last method does not so clearly show the obliquity of the axis of the earth to the plane of its orbit, take a board of any convenient dimensions, suppose two feet across, on which describe a circle, or an ellipsis differing little from a circle, draw a diameter OFO, (*Plate* III. *Fig.* i.) and parallel to this diameter let several lines *e f* be drawn, then bore several holes perpendicularly down in the points *e e*, *&c.* of the circumference of the circle; take two pieces of wire crossing each other in an agle of 23° 28′; as *a g* and *n f*, of which *a g* the perpendicular wire is the longer, and connect them by a straight wire *e f;* then placing a small globe on the point *n*, and a light in the centre of the circle of the same height as the centre of the little globe; let the point *g* in the longer wire be fixed successively in the holes *e e*, &c. in the circumference of the circle, so that the base *e*, *f*, of the wire may rest on the lines *e f* in the plane of the earth's orbit, the seasons of the year will be agreeably and accurately illustrated. If the little globe be placed upon the point *a*, instead of the point *n*, and the same method be observed in moving the wires round the orbit, there will be no diversity of seasons. The diurnal revolution of the earth may be shown by moving the globe round the wire *n f*, as an axis, with the finger.

Dr. Halley* says, the vapours that are raised copiously from the sea, and carried by the winds to the ridges of mountains, are conveyed to their tops by the current of air; where the water being presently precipitated, enters the crannies of the mountains, down which it glides into the caverns, till it meets with a stratum of earth or stone, of a nature sufficiently solid to sustain it. When this reservoir is filled, the superfluous water, following the direction of the stratum, runs over at the lowest place, and in its passage meets perhaps with other little streams, which have a similar origin; these gradually descend till they meet with an aperture at the side, or foot of the mountain, through which they escape, and form a spring, or the source of a brook or rivulet. Several brooks or rivulets, uniting their streams, form small rivers; and these again being joined by other small rivers, and united in one common channel, form such streams as the Rhine, Rhone, Danube, &c.

Several springs yield always the same quantity of water equally when the least rain or vapour is afforded, as when rain falls in the greatest quantities; and as the fall of rain, snow, &c. is inconstant or variable, we have here a constant effect produced from an inconstant cause, which is an unphilosophical conclusion. Some naturalists, therefore, have recourse to the sea, and derive the origin of several springs immediately from thence, by supposing a subterraneous circulation of percolated waters from the fountains of the deep.

That the sun exhales as much vapour as is sufficient for rain, is past dispute, having been several times proved by actual experiments. Dr. Halley† determined by experiment and calculation‡, that in a summer's day, there may be raised in vapours from the Mediterranean 5280 millons of tons of water, and yet the Mediterranean does not receive from all its rivers above 1827 millions of tons in a day, which is little more than a third part of what is exhausted by vapours§; and from the river Thames, twenty millions three hundred thousand tons may be raised in one day in a similar manner.—In the Old Continent, there are about 430 rivers which fall directly into the ocean, or into the Mediterranean and Black Seas, and in the New Continent, scarcely 180 rivers are known, which fall directly into the sea; but in this number, only the greater rivers are comprehended.* All these rivers carry to the sea a great quantity of mineral and saline particles, which they wash from the different soils through which they pass, and the particles of salt, which are easily dissolved, are conveyed to the sea by the water. Dr. Halley imagines that the saltness of the sea proceeds from the salts of the earth only, which rivers convey thither, and that it was originally fresh. So that its saltness will continue to increase; for, the vapours which are exhaled from the sea are entirely fresh, or devoid of saline particles. Others imagine that there is a great number of rocks of salt at the bottom of the sea, and from these rocks it acquires its saltness. Some writers, again, have imagined that the sea was created salt that it might not corrupt; but it may well be supposed that the sea is preserved from corruption by the agitations of the wind, and from the flux and reflux of the tide, as much as by the salt it contains, for, when sea-water is kept in a barrel, it corrupts in a few days. The Honourable Mr. Boyle† relates that a mariner, becalmed for thirteen days, found at the end of that time, the sea so infected, that if the calm had continued, the greatest part of his people on board would have perished.—The sea is nearly equally salt throughout, under the equinoctial line and at the Cape of Good Hope, though there are some places on the Mozambique coast where it is salter than elsewhere. It is also asserted that it is not quite so salt under the arctic circle as in some other latitudes‡; this probably may proceed from the great quantity of snow, and the great rivers which fall into those seas: to which we may add, that the sun does not draw such quantities of fresh water, or vapours, from those seas as in hot countries.

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* Philosophical Transactions, No. 192.

† Dr. Halley was an eminent mathematician, astronomer, and philosopher, born in London in the year 1656.

‡ Philosophical Transactions, No. 212.

§ As evaporation cannot carry off fixed salts, it would appear that if the above calculation be accurate, the Mediterranean would be more salt than the ocean, but it must be remembered that a current sets constantly out of the Atlantic Ocean into the Mediterranean.

It is worthy of remark that all lakes from which rivers derive their origin, or which fall into the course of rivers, are not saline;§

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* Buffon's Natural History.

† A younger son of the Earl of Cork, and one of the most celebrated philosophers in Europe, born at Lismore, in the county of Waterford, 1626-7. See his treatise on the Saltness of the Sea, published in 1674.

‡ In a *System of Chemistry*, by Dr. *Thompson*, of Edinburgh, Vol. iv. *fourth edition*, page 141, it is stated, that the ocean contains most salt between 10° and 20° south latitude, and that the proportion of salt is the least in latitude 57° north.

§ Buffon's Natural History, Chap. II.

and almost all those, on the contrary, which receive rivers, without other rivers issuing from them, are saline: this seems to favour Dr. Halley's opinion respecting the saltness of the sea; for evaporation cannot carry off fixed salts, and consequently those salts which rivers carry into the sea remain there. It is asserted* to be the peculiar property of sea-water, that when it is absolutely salt, it never freezes; and that the islands or rocks of ice which float in the sea near the poles, are originally frozen in the rivers, and carried thence to the sea by the tide; where they continue to accumulate by the great quantities of snow and sleet which fall in those seas. According to this opinion, great quantities of ice can be produced only from great quantities of fresh water, or from large rivers; and as large rivers can only flow from large tracts of land, it would appear that there must be immense tracts of land near the south pole, for the Antarctic Ocean abounds with fields or mountains of ice, as well as the Arctic Ocean; but our circumnavigators have traversed the Southern Ocean to upwards of seventy degrees south latitude, without discovering any land.† With respect to the freezing of salt water, we have several instances of the Baltic ‡ and other seas being frozen over, when the ice on the surface could never proceed from rivers. It is true that the sailors frequently take large pieces of the rocks of ice, and thaw them for the use of the ship's company, and always find the water fresh; but it does not follow from this that the ice is formed in the rivers. As fresh water only is extracted from sea-water by the heat of the sun, and carried into the atmosphere, may not the fresh, without the saline particles of sea-water, be converted into ice by extreme cold?

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* Emerson's Geography, page 64.

† Mr. William Smith, master of the brig Williams, of Blythe, Northumberland, in a voyage from Buenos Ayres to Valparaiso, in Chili, in order more easily to weather Cape Horn, steered an unusual southerly course, and on the 19th of February 1819, lat. 62° 17′ S. long. 60° 12′ W. discovered land: he afterwards ascertained the existence of the coast for the distance of 250 miles. An account of this discovery, with plates of the appearance of the land, &c. may be seen in the Edinburgh Philosophical Journal, Vol. III. October 1820, page 367. This newly-discovered land is called *New South Shetland.*

‡ The Baltic Sea is not so salt as the ocean, and the proportion of salt is increased by a west wind, and still more by a north-west wind: a proof that not only the saltness of the Baltic is derived from the ocean, but that storms have a much greater effect upon the waters of the ocean than has been supposed. Dr. *Thompson's Chemistry,* vol. iv. page 141.—The Baltic Sea has little or no tides, and a current runs constantly through the Sound into the Cattegate Sea.

## CHAPTER VI.

### *Of the Flux and Reflux of the Tides.*

A TIDE is that motion of the water in the seas and rivers, by which they are found to rise and fall in a regular succession; and this flowing and ebbing is caused by the attraction of the sun and moon.*

Suppose the earth to be entirely covered by a fluid as A, B, Z, C, D, Q, N. (*Plate* III. *Figure* 2.) and the action of the sun and moon to have no effect upon it, then it is evident that all the particles, being equally attracted towards the centre O of the earth, would form an exact spherical surface; except, that by the revolution of the earth on its axis N′ S′, the attraction from B towards O, and from Q towards O would be a little diminished by the centrifugal force. Let the moon at M now exert her influence upon the water; then because the power of attraction diminishes as the square of the distance increases, those parts will be the most attracted which are nearest to the moon, and their tendency towards O will be diminished: the waters at Z, B, and C, will therefore rise, and at Z, which is nearest to the moon, they will be the highest; but when the waters in the zenith Z are elevated, those in the nadir N are likewise elevated in a similar manner; this is known from experience, for we have high water when the moon is in our nadir as well as when she is in our zenith; we therefore conclude that, when the moon is in our zenith, our antipodes have high water: the truth of this, as well as every other phenomenon respecting the tides, will be discussed in the following theorems.

THEOREM I.† *The parts of the earth directly under the moon, or where the moon is in the Zenith as at* Z; (Plate III. Figure 3.) *and those places which are diametrically opposite to the former, or under the Nadir as at* N, *will have high water at the same time:*

Because the power of gravity decreases as the square of the distance increases; the waters at A, B, Z, C, D, on the side of the earth next the moon M, will be more attracted by the moon than the central parts O of the earth, and the central parts will be more attracted than the surface N on the opposite side of the earth; therefore the distance between the centre of the earth and the surface of the water, under the zenith and nadir, will be increased. For, let three bodies, Z, O, and N, be equally attracted by M; then it is evident they will all move equally fast towards M, and their mutual distances from each other will continue the same; but if the bodies be unequally attracted by M, that body which is the most attracted will move the fastest, and its distance from the other bodies will be increased. Now, by the law of gravitation, M will attract Z more strongly than it does O, by which the distance between Z and O will be increased. In like manner O being more strongly attracted than N, the distance between O and N will be increased; suppose now a number of bodies, A, B, Z, C, D, F, N, E, placed round O, to be attracted by M, the parts Z and N will have their distances from O increased; while the parts A and D, being nearly at the same distance from M as O is, will not recede from each other, but will rather approach near to O by the oblique attraction of M. Hence if the whole earth were composed of bodies similar to A, B, Z, C, D, F, N, E, and to be similarly attracted by M, the section of the earth, formed by a plane passing through the moon and the earth's centre, would be a figure resembling an ellipsis, having its longer axis ZN directed towards the moon; and its shorter axis AD in the horizon. The figure of the earth therefore would be an oblong spheroid having its longer axis directed to the moon, consequently it will be high water in the zenith and nadir at the same time; and as the earth turns round its axis from the moon to the moon again in about 24 hours and 48 minutes, there will be two tides of flood and two of ebb in that time, agreeably to experience.

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* This was known to the ancients: Pliny expressly says that the cause of the ebb and flow is in the sun, which attracts the waters of the ocean, and that they also rise in proportion to the proximity of the moon to the earth. Dr. *Hutton's* Math. Dictionary, word Tides.

† A theorem is a proposition which admits of proof, or demonstration, from definitions clearly understood, and from the known general properties of the subject under consideration.

According to the foregoing explanation of the ebbing and flowing of the sea, every part of the earth is gravitating towards the moon; but as the earth revolves round the sun, every part of it gravitates towards the sun likewise; it may be asked how is this possible at the time of full moon, when the moon is at *m* and the sun at S; has the earth a tendency to fall contrary ways at the same time? This is a very natural question, but it must be considered that it is not the centre of the earth that describes the annual orbit round the sun, but the common centre of gravity of the earth and moon together; and that whilst the earth is moving round the sun, it also describes a circle round that centre of gravity, about which it revolves as many times as the moon revolves round the earth in a year.* The earth is therefore constantly falling towards the moon, from a tangent to the circle which it describes round the common centre of gravity of the earth and moon. Let M represent the moon, (*Plate* III. *Figure* 4.,) TW a part of the moon's orbit, and as the earth is supposed to contain about forty times the quantity of matter which is contained in the moon, the common centre of gravity from the centre of the earth towards the moon will be considerably less than the earth's diameter.* Let this common centre of gravity be represented by C. Then whilst the moon goes round her orbit, the centre of the earth describes the circle *d o e* round C, to which circle *o a* is a tangent: therefore when the moon has gone from M to a little past W, the earth has moved from *o* to *e;* and in that time has fallen towards the moon from the tangent at *a* to *e*. This figure is drawn for the new moon, but the earth will tend towards the moon in the same manner during its whole revolution round C.

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* Ferguson's Astronomy, Article 298.

THEOREM II. *Those parts of the earth where the moon appears in the horizon, or* 90 *degrees distant from the Zenith and Nadir, as at* A *and* D (Plate III. Figure 3.) *will have ebb or low water:*

For, as the waters under the zenith and nadir rise at the same time, the waters in their neighbourhood will press towards those places to maintain the equilibrium; and to supply the place of these waters, others will move the same way, and so on to places of 90 degrees distance from the zenith and nadir; consequently at A and D where the moon appears in the horizon, the waters will have more liberty to descend towards the centre of the earth;

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* The common centre of gravity of two bodies is found thus: as the sum of the weights, or quantities of matter in the two bodies is to their distance from each other, so is the weight of the less body to the distance of the greater from the centre of gravity. Now if the quantity of matter in the moon be represented by 1, that in the earth by (40), and the distance of the earth from the moon be estimated at 240,000 miles, then (40 + 1) : 240,000 : : 1 : (5853) miles, the distance of the centre of the earth from the common centre of gravity. Mr. A. Walker, in the 11th lecture of his Familiar Philosophy, ingeniously accounts for its being high water in the zenith and nadir at the same time, in the following manner. "The parts of the earth that are farthest from the moon, will have a swifter motion round the centre of gravity than the other parts; thus the side *n* will describe the circle *n* V Y, while the side *m* will only describe the small circle *m r s*, round the centre of gravity *c*. Now, as every thing in motion always endeavours to go forward in a straight line, the water at *n* having a tendency to go off in the line *n q*, will in a degree overcome the power of gravity, and swell into a heap or protuberance, as represented in the figure, and occasion a tide opposite to that caused by the attraction of the moon."

and therefore in those places they will be the lowest. Hence it plainly appears, that the ocean, if it covered the whole surface of the earth, would be a spheroid, (as was observed in the foregoing theorem,) the longer diameter, as ZN, passing through the place where the moon is vertical, and the shorter diameter, as AD, passing through the rational horizon of that place. And as the moon apparently[*] shifts her position from east to west in going round the earth every day, the longer diameter of the spheroid following her motion will occasion the two floods and ebbs in about 24 hours and 48 minutes[†], the time which any meridian of the earth takes in revolving from the moon to the moon again; or the time elapsed (at a medium) between the passage of the moon over the meridian of any place, to her return to the same meridian.

The meridian altitude of the moon at any place is her greatest height above the horizon at that place, hence the greater the moon's meridian altitude is, the greater the tides will be; for they increase from the horizon D to the point Z under the zenith, and the greater the moon's meridian depression is below the horizon, the greater the tides will be; for they increase from the horizon D towards N the point below the nadir, and consequently as the tides increase from D to N, the tides in their antipodes will increase from A to Z.

THEOREM III. *The time of high water is not precisely at the time of the moon's coming to the meridian, but about an hour after:*

For, the moon acts with some force after she has passed the meridian, and by that means adds to the libratory or waving motion, which the waters had acquired whilst she was on the meridian.

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[*] The real motion of the moon is from the west towards the east; for if she be seen near any fixed star on any night, she will be seen about 13 degrees to the eastward of that star the next night, and so on. The moon goes round her orbit from any fixed star to the same again in about 27 days and 8 hours. Hence 27 d. 8 h. : 360° : : 1 d. : 13° 10′ 41″.6, the mean motion of the moon in 24 hours.

[†] The mean motion of the moon in 24 hours is 13° 10′ 14″.6, and the mean apparent motion of the sun in the same time is 59′ 8″.2, (*see the note to definition* 61. *page* 14.) the moon's motion is therefore 12 11′ 6″.4 swifter than the apparent motion of the sun in one day, which, reckoning 4 minutes to a degree, amounts to 48 minutes 44 seconds of time.

THEOREM IV. *The tides are greater than ordinary twice every month; viz. at the time of new and full moon, and these are called* SPRING-TIDES: (Plate III. Figure III.)

For at these times the actions of both the sun and moon concur to draw in the same straight line SMZON, and therefore the sea must be more elevated. In conjunction, or at the new moon, when the sun is at S and the moon at M both on the same side of the earth, their joint forces conspire to raise the water in the zenith at Z, and consequently (according to Theorem I.) at N the nadir likewise.* When the sun and moon are in opposition, or at the full moon when the sun is at S and the moon at *m*, the earth being between them; while the sun raises the water at Z under the zenith and at N under the nadir, the moon raises the water at N under the nadir and at Z under the zenith.

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* Mr. Walker says (Lecture 11th), that at new moon "The sun's influence is added to that of the moon, and the centre of gravity c (*Plate* III. *Figure* 4.) will, therefore, be removed farther from the earth than mc, and of course, increase the centrifugal tendency of the tide *n*: hence both the attracted and centrifugal tides are spring-tides at that time.—" But spring-tides take place at the full as well as at the change of the moon. Now it has been premised, that if we had no moon, the sun would agitate the ocean in a small degree and make *two* tides every twenty-four hours, though upon a small scale. The moon's centrifugal tide at Z (*Plate* III. *Figure* 3.) being increased by the sun's attraction at S, will make the protuberance a spring-tide; and the *sun's centrifugal tide* at N will be reinforced by the moon's attraction at *m*, and make the protuberance N a spring-tide; so spring-tides take place at the full as well as at the change of the moon."—Suppose the moon to be taken away (*Plate* III. *Figure* 4.) the common centre of gravity of the earth and the sun would fall entirely within the body of the sun, round which the earth revolves in a year, at the rate of about a degree in a day; hence the parts *n* of the earth farthest from the sun would have a little more tendency to recede from the centre of motion S, than the parts *m* which are the nearest. So that if the sun were on the meridian of any place it would be high water at that place by the sun's attraction, and it would at the same time be high water at the antipodes of that place by the centrifugal tendency of *n*; consequently as the earth revolves on its axis from noon to noon in 24 hours, there would be two tides of flood and two of ebb during that time. If the line *m* c be increased when the moon is in conjunction with the sun, so as to cause the point *n* to describe a larger circle than *n* V T, and also the point *m* to describe a larger circle than *m r s* round the centre of gravity c; when the sun is in opposition to the moon, the line *m* c will be diminished, *n* will therefore describe a smaller circle than *n* V T, and *m* will describe a smaller circle than *m r s*. Hence it appears that the centrifugal tendency of *n* is greater at the new moon than it is at the full moon, and *m* is likewise more strongly attracted at the same time; the spring-tides at the time of conjunction would therefore be considerably greater than at the time of opposition, were not the moon's centrifugal tide at this time attracted by the sun, and the sun's centrifugal tide added to to that caused by the moon's attraction.

THEOREM V. *The tides are less than ordinary twice every month; that is, about the time of the first and last quarters of the moon, and these are called* NEAP-TIDES: (Plate III. Figure 3.)

Because in the quadratures, or when the moon is 90 degrees from the sun, the sun acts in the direction SD and elevates the water at D and A; and the moon acting in the direction MZ or *m*N elevates the water at Z and N; so that the sun raises the water where the moon depresses it, and depresses the water where the moon raises it; consequently the tides are formed only by the difference between the attractive force of the sun and moon.—The waters at Z and N will be more elevated than the waters at D and A, because the moon's attractive force is four* times that of the sun.

THEOREM VI. *The spring tides do not happen exactly on the day of the change or full moon, nor the neap-tides, exactly on the days of the quarters, but a day or two afterwards.*

When the attractions of the sun and moon have conspired together for a considerable time, the motion impressed on the waters will be retained for some time after their attractive forces cease, and consequently the tide will continue to rise. In like manner at the quarters, the tide will be the lowest when the moon's attraction has been lessened by the sun's for several days together.—If the action of the sun and moon were suddenly to cease, the tides would continue their course for some time, as the waves of the sea continue to be agitated after a storm.

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* Sir Isaac Newton, Cor. 3 Prop. XXXVII. Book III. Princip. makes the force of the moon to that of the sun, in raising the waters of the ocean, as 4.4815 to 1: and in Corol. 1. of the same proposition he calculates the height of the solar tide to be 2 feet 0 inch ¼, the lunar tide 9 feet 1 inch ¾, and by their joint attraction 11 feet 2 inches; when the moon is in Perigee the joint forces of the sun and moon will raise the tides upwards of 13¼ feet.—Sir Isaac Newton's measures are in French feet in the Principia. I have turned them into English feet.

Mr. Emerson, in his Fluxions, Section III. Prob. 25. calculates the greatest height of the solar tide to be 1.63 feet, the lunar tide 7.28 feet, and by their joint attraction 8.91 feet, making the force of the sun to that of the moon as 1 to 4.4815.

Dr. Horsely, the late bishop of St. Asaph, estimates the force of the moon to that of the sun as 5.0469 to 1. See his edition of the Principia, lib. 3. Sect. 3. Prop. XXXVI. and XXXVII.

Mr. Walker, in Lect. 11th of his Familiar Philosophy, states the influence of the sun to be to the influence of the moon to raise the water, as 3 is to 10, and their joint force 13.

**Theorem VII.** *When the moon is nearest to the earth, or in Perigee, the tides increase more than in similar circumstances at other times:*

For the power of attraction increases as the square of the distance of the moon from the earth decreases; consequently the moon must attract most when she is nearest to the earth.

**Theorem VIII.** *The spring-tides are greater a short time before the vernal equinox, and after the autumnal equinox, viz. about the latter end of March and September, than at any other time of the year:* (Plate III. Figure III.)

Because the sun and moon will then act upon the equator in the direction *a f* B, consequently the spheroidal figure of the tides will then revolve round its longer axis, and describe a greater circle than at any other time of the year; and as this great circle is described in the same time that a less circle is described, the waters will be thrown more forcibly against the shores in the former circumstances than the latter.

**Theorem IX.** *Lakes are not subject to tides; and small inland seas, such as the Mediterranean and Baltic, are little subject to tides. In very high latitudes north or south the tides are also inconsiderable.*

The lakes are so small, that when the moon is vertical she attracts every part of them alike. The Mediterranean and Baltic seas have very small elevations, because the inlets by which they communicate with the ocean are so narrow, that they cannot, in so short a time, receive or discharge enough to raise or lower their surfaces sensibly.

**Theorem X.** *The time of the tides happening in particular places, and likewise their height, may be very different according to the situation of these places:*

For the motion of the tides is propagated swifter in the open sea, and slower through narrow channels or shallow places; and being retarded by such impediments the tides cannot rise so high.

## GENERAL OBSERVATION.

The new and full moon spring-tides rise to different heights.

The morning tides differ generally in their rise from the evening tides.

In winter the morning tides are highest.

In summer the evening tides are highest.

The tides follow or flow towards the course of the moon, when they meet with no impediment. Thus the tide on the coast of Norway flows to the south (towards the course of the moon); from the North-cape in Norway to the Naze at the entrance of the Scaggerac, or Cattegate Sea, where it meets with the current which sets constantly out of the Baltic Sea, and consequently prevents any tide rising in the Scaggerac. The tide proceeds to the southward, along the east coast of Great Britain, supplying the ports successively with high water, beginning first on the coast of Scotland. Thus it is high water at Tynemouth Bar, at the time of new and full moon, about three hours after the time of high water at Aberdeen; it is high water at Spurn-head about two hours after the time of high water at Tynemouth Bar; in an hour more it runs down the Humber, and makes high water at Kingston upon Hull; it is about three hours running from Spurn-head to Yarmouth Road; one hour in running from Yarmouth Road to Yarmouth Pier; 2½ hours running from Yarmouth Road to Harwich; 1½ hour in passing from Harwich to the Nore, from whence it proceeds up the Thames to Gravesend and London. From the Nore, the tide continues to flow southward to the Downs and Godwin Sands, between the north and south Foreland in Kent, where it meets the tide which flows out of the English Channel, through the Strait of Dover.

While the tide, or high water, is thus gliding to the southward, along the eastern coast of Great Britain, it also sets to the southward along the western coasts of Scotland and Ireland; but, on account of the obstructions it meets with by the Western Islands of Scotland, and the narrow passage between the north-east of Ireland and the south-west of Scotland, the tide in the Irish Sea comes round by the south of Ireland through St. George's Channel, and runs in a north-east direction till it meets the tide between Scotland and Ireland at the north-west part of the Isle of Man. This may be naturally inferred from its being high water at Waterford above three hours before it is high water at Dublin, and it is high water at Dundalk Bay and the Isle of Man nearly at the same time. That the tide continues its course southward may be inferred from its being high water at Ushant, opposite to Brest in France, about an hour after the time of high water at Cape Clear, on the southern coast of Ireland. Between the Lizard Point in Cornwall and the Island of Ushant, the tide flows eastward, or east-north-east, up the English Channel, along the coasts of England and France, and so on through the Straits of Dover, till it comes to the Godwin Sands or Galloper, where it meets the tide on the eastern coast of England, as has been observed before. The meeting of these two tides contributes greatly towards sending a powerful tide up the river Thames to London; and, when the natural course of these two tides had been interrupted by a sudden change of the wind, so as to accelerate the tide which it had before retarded, and to drive back that tide which had before been driven forward by the wind, this cause has been known to produce twice high water in the course of three or four hours. The above account of the British tides seems to contradict the general theory of the motion of the tides, which ought always to follow the moon, and flow from east to west; but to allow the tides their full motion, the ocean in which they are produced ought to extend from east to west at least 90 degrees, or 6255 English miles; because that is the distance between the places where the water is most raised and depressed by the moon. Hence it appears that it is only in the great oceans that the tide can flow regularly from east to west; and hence we also see why the tides in the Pacific Ocean exceed those in the Atlantic, and why the tides in the torrid zone, between Africa and America, though nearly under the moon, do not rise so high as in the temperate zones northward and southward, where the ocean is considerably wider. The tides in the Atlantic, in the torrid zone, flow from east to west till they are stopped by the continent of America; and the trade winds likewise continue to blow in that direction. When the action of the moon upon the waters has in some degree ceased, the force of the trade winds, in a great measure prevents their return towards the African shores. The waters thus accumulated* in the gulf of Mexico, return to the Atlantic between the island of Cuba, the Bahama islands, and East Florida, and form that remarkable strong current called the gulf of Florida.

Newton's discovery of the law of gravitation naturally led to the true origin of the tides. That great author has shown, in the third book of his Principia, that the tides are produced by the disturbing forces of the sun and moon.

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* To show that an accumulation of water does take place in the gulf of Mexico, a survey was made across the isthmus of Darien, when the water on the Atlantic was found to be 14 feet higher than the water on the Pacific side. Walker's Familiar Philosophy, Lecture xi.

In 1740 the theory of Newton was completely developed in the Prize Essays of M‘Laurin, Euler, and Bernoulli, of which an excellent abstract is given in the first volume of Robinson's Natural Philosophy.

Laplace is the only mathematician who has advanced, in this most difficult problem, beyond the theory of Newton. Instead of the statical equilibrium employed by Newton, and those who have followed his method, Laplace in his Mecanique Celeste, considers the subject in its true point of view, as a problem in Hydrodynamics, in which the oscillations of the waters of the ocean are to be derived from the accelerating forces, by the analytic formulæ that express the motion of fluids.

## CHAPTER VII.

### *Of the Natural Changes of the Earth, caused by Mountains, Floods, Volcanoes, and Earthquakes.*

That there have always been mountains from the foundation of the world, is as certain as that there have always been rivers, both from reason and revelation*; for they were as necessary before the flood for every purpose as they are at present. If the earth were perfectly level, there could be no rivers, for water can flow only from a higher to a lower place; and instead of that beautiful variety of hills and valleys, verdant fields, forests, &c. which serve to display the goodness and beneficence of the Deity, a dismal sea would cover the whole face of the earth, and render it at best an habitation for aquatic animals only.

All mountains and high places continually decrease in height. Rivers running near mountains undermine and wash a part of them away, and rain falling on their summits washes away the loose parts, and saps the foundations of the solid parts, so that, in the course of time, they tumble down. Thus, old buildings on the tops of mountains are observed to have their foundations laid bare by the gradual washing away of the earth. In plains and valleys we find a contrary effect; the particles of earth washed down from the hills fill up the valleys, and ancient houses built in low places seem to sink. For the same reason a quantity of mud, slime, sand, earth, &c. which is continually washed down from the higher places into the rivers, is carried by the stream, and by degrees chokes up the mouths of rivers, especially when the soil through which they run is of a loose and rich quality. Thus, the water of the river Mississippi, though wholesome and well tasted, is so muddy, that a sediment of two inches of slime has been found in a half-pint tumbler of it*; this river is choked up at the mouth with the mud, trees, &c. which are washed down it by the rapidity of the current.

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* Four rivers, or rather four branches of one river, are expressly mentioned before the flood, viz. *Pison*, *Gihon*, *Hiddekel*, and the *Euhprates*. Genesis, chap. ii. And in the 7th chapter of Genesis, at the time of the flood, we are told that the fountains of the great deep were broken up, the windows of heaven were opened, the waters prevailed exceedingly upon the earth, and all the high hills and the mountains were covered.

The highest mountains in the world are the Andes†, in South America, which extend near 4300 miles in length, from the province of Quito to the strait of Magellan; the highest, called Chimboraço, is said to be 20608 feet, or nearly four miles above the level of the sea: 2400 feet of which, from the summit, are always covered with snow. From experiments made with a barometer‡ on the mountain Cotopaxi, another part of the Andes, it appeared that its summit was elevated 6252 yards, or upwards of 3 1-2 miles above the surface of the sea. There is a mountain in the island of Sumatra, called Ophir by the Europeans, the summit of which is 13842 feet high: the Peak of Teneriffe, in the island of that name, is said to be 13265 feet or upwards of 2 1-2 miles high. Mont Blanc, the highest mountain in Europe, is 15304 feet above the level of the sea. These irregularities, although very considerable with respect to us, are nothing when compared with the magnitude of the globe. Thus, if an inch were divided into one huudred and ten parts, the elevation of Chimboraço, the highest of the Andes, on a globe of eighteen inches in diameter, would be represented by *one*§ of these parts.

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* Morse's American Geography.

† Perhaps the Himalaya mountains are an exception, *See the Note*, page 58.

‡ The quicksilver in a barometer falls about one-tenth of an inch every 32 yards of height; so that, if the quicksilver descend three-tenths of an inch in ascending a hill, the perpendicular height of that hill will be 96 yards. This method is liable to error. See the causes which affect the accuracy of Barometrical experiments, in the Edinburgh Philosophical Transactions, by Mr. Playfair; also in Keith's Trigonometry, fourth edition, page 97.

Hence, the earth, which appears to be crossed by the enormous height of mountains, and cut by the valleys and the great depth of the sea, is nevertheless, with respect to its magnitude, only very slightly furrowed with irregularities, so trifling indeed as to cause no difference in its figure.

Having, in some measure, accounted for the descending of the earth from the hills, and filling up the valleys, stopping the mouths of rivers, &c. which are gradual, and much the same in all ages, the more remarkable changes may be reduced to two general causes, floods and earthquakes.

The real or fabulous deluges mentioned by the ancients may be reduced to six or seven, and though some authors have endeavoured to represent them all as imperfect traditions of the universal deluge recorded in the sacred writings, the Abbè Mann,[*] from whom the following observations are extracted, does not doubt but that they refer to various real and distinct events of the kind.

1. The submersion of the *Atlantis* of Plato probably was the real subsidence of a great island stretching from the Canaries to the Azores, of which those groups of small islands are the relics.

2. The deluge in the time of Cadmus[†] and Dardanus, placed by the best chronologists in the year before Christ 1477, is said by Diodorus Siculus to have inundated Samothrace, and the Asiatic shores of the Euxine Sea.

3. The deluge of Deucalion, which the Arundelian marbles,[‡] or the Parian chronicles, fix at 1529 years before Christ, overwhelmed Thessaly.

4. The deluge of Ogyges, placed by Acusilaus in the year answering to 1796 before Christ, laid waste Attica and Bœotia. With the poetical and fabulous accounts of Deucalion's flood are mingled several circumstances of the universal deluge; but the best writers attest the locality and distinctness both of the flood of Deucalion and Ogyges.

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[*] Vide Nouveaux Memoires de l'Academie Imperiale et Royale de Sciences et des Belles Lettres, de Brussels, tome premier, 1788.

[†] The ancient names which occur here may all be found in Lempriere's Classical Dictionary.

[‡] Ancient stones, whereon is inscribed a chronicle of the city of Athens, engraven in capital letters, in the island of Paros, one of the Cyclades, 264 years before Christ. They take their name from Thomas, Earl of Arundel, who procured them from the East. They were presented to the University of Oxford in the year 1667, by the Hon. Henry Howard, afterwards Duke of Norfolk, grandson to the first collector of them.

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5. Diodorus Siculus, after Manetheo, mentions a flood which inundated all Egypt in the reign of Osiris; but, in the relations of this event, are several circumstances resembling the history of Noah's flood.

6. The account given by Berosus the Chaldean of an universal deluge in the reign of Xisuthrus, evidently relates to the same event with the flood of Noah.

7. The Persian Guebres, the Bramins, Chinese, and Americans have also their traditions of an universal deluge. The account of the deluge in the Koran has this remarkable circumstance, that the waters which covered the earth are represented as proceeding from the boiling over of the cauldron,* or oven, *Tannour*, within the bowels of the earth: and that, when the waters subsided, they were swallowed up again by the earth.

The Abbè next gives a summary of the Scripture account of Noah's flood, and points out very clearly that part of the waters came from the atmosphere, and part from under ground agreeably to the 11th verse of the viith chapter of Genesis.

Earthquakes are another great cause of the changes made in the earth. From history, we have numerous instances of the dreadful and various effects of these terrible phenomena. Pliny has not only recorded several extraordinary phenomena which happened in his own time, but has likewise borrowed many others from the writings of more ancient nations.

1. A city of the Lacedemonians was destroyed by an earthquake, and its ruins wholly buried by the mountain Taygetus falling down upon them.†

2. In the books of the Tuscan learning an earthquake is recorded, which happened within the territory of Modena, when L. Martius and S. Julius were consuls, which repeatedly dashed two hills against each other; with this conflict all the villages and many cattle were destroyed.

3. The greatest earthquake mentioned in history was that which happened during the reign of Tiberius Cæsar when twelve cities of Asia were laid level in one night.‡

4. The eruption of Vesuvius, in the year 79,§ overwhelmed

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* This circumstance is mentioned here, because it agrees with Mr. Whitehurst's theory of the earth; he supposes the flood was occasioned by the expansive force of fire generated at the centre of the earth.

† Pliny's Natural History, chap. 79.

‡ Pliny, chap. 84.

§ Pliny lost his life by this eruption, from two eager a curiosity in viewing the flames.

the two famous cities of Herculaneum[*] and Pompeii, by a shower of stones, cinders, ashes, sand, &c. and totally covered them many feet deep, as the people were sitting in the theatre. The former of these cities was situated about four miles from the crater, and the latter about six.

By the violence of this eruption, ashes were carried over the Mediterranean sea into Africa, Egypt, and Syria; and at Rome they darkened the air on a sudden, so as to hide the face of the sun.[†]

5. In the year 1533, large pieces of rock were thrown to the distance of fifteen miles, by the volcano Cotopaxi in Peru.[‡]

6. On the 29th September 1535, previous to an eruption near Puzzoli, which formed a new mountain of three miles in circumference, and upwards of 1200 feet perpendicular height, the earth frequently shook, and the plain lying between the lake Averno, mount Barbaro, and the sea was raised a little; at the same time the sea, which was near the plain, retired two hundred paces from the shore.[§]

7. In the year 1538, a subterraneous fire burst open the earth near Puzzoli, and threw such a vast quantity of ashes and pumice stones, mixed with water, as covered the whole country, and thus formed a new mountain, not less than three miles in circumference, and near a quarter of a mile perpendicular height. Some of the ashes of this volcano reached the vale of Diana, and some parts of Calabria, which are more than one hundred and fifty miles from Puzzoli.[‖]

8. In the year 1538, the famous town called St. Euphemia, in Calabria Ulterior, situated at the side of the bay under the jurisdiction of the knights of Malta, was totally swallowed up with all its inhabitants, and nothing appeared but a fetid lake in the place of it.[¶]

9. A mountain in Java, not far from the town of Panacura, in the year 1586, was shattered to pieces by a violent eruption of glowing sulphur (though it had never burnt before,) whereby ten thousand people perished in the underland fields.[**]

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[*] This city was discovered in the year 1736, eighty feet below the surface of the earth; and some of the streets of Pompeii, &c. have since been discovered.

[†] Burnet's Sacred History, page 85, vol. ii.

[‡] Ulloa's Voyage to Peru, vol. i. p. 324.

[§] Sir William Hamilton's Observations on Vesuvius.

[‖] Ibid. p. 128.

[¶] Dr. Hooke's Post. p. 306.

[**] Varenius's Geography, vol. i. p. 150.

10. In the year 1600, an earthquake happened at Arquepa, in Peru, accompanied with an eruption of sand, ashes, &c. which continued during the space of twenty days, from a volcano breaking forth; the ashes falling in many places, above a yard thick, and in some places more than two, and where least, above a quarter of a yard deep, which buried the corn grounds of maize and wheat. The boughs of trees were broken, and the cattle died for want of pasture; for the sand and ashes thus erupted, covered the fields ninety miles one way, and one hundred and twenty an other way. During the eruption, mighty thunders and lightnings were heard and seen ninety miles round Arquepa, and it was so dark whilst the showers of ashes and sand lasted, that the inhabitants were obliged to burn candles at mid-day.*

11. On the 16th of June, 1628, there was so terrible an earthquake in the island of St. Michael, one of the Azores, that the sea near it opened, and in one place where it was one hundred and sixty fathoms deep, threw up an island; which in fifteen days was three leagues long, a league and a half broad, and 360 feet above the water.†

12. In the year 1631 vast quantities of boiling water flowed from the crater of Vesuvius previous to an eruption of fire; the violence of the flood swept away several towns and villages, and some thousands of inhabitants.‡

13. In the year 1632, rocks were thrown to the distance of three miles from Vesuvius.§

14. In the year 1646, many of those vast mountains, the Andes,‖ were quite swallowed up and lost.¶

15. In the year 1692, a great part of Port Royal, in Jamaica, was sunk by an earthquake, and remains covered with water several fathoms deep; some mountains along the rivers were joined together, and a plantation was removed half a mile from the place where it formerly stood.**

16. On the 11th January, 1693, a great earthquake happened in Sicily, and chiefly about Catania; the violent shaking of the earth threatened the whole island with entire desolation. The earth opened in several places in very long clefts, some

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* Dr. Hooke's Post. p. 304.

† Sir W. Hamilton's Observations on Vesuvius and Ætna, p. 159.

‡ Ibid.

§ Baddam's Abridg. Phil. Trans. vol. ii. p. 417.

‖ M. Condamine represents these mountains and the Appenines as chains of volcanoes. See his Tour through Italy, 1755.

¶ Dr. Hooke's Post. p. 306.

** Lowthorp's Abridg. Phil. Trans. vol. ii. p. 417.

three or four inches broad, others like great gulfs. Not less than 59,969 persons were destroyed by the falling of houses in different parts of Sicily.*

17. In the year 1699, seven hills were sunk by an earthquake in the island of Java, near the head of the great Batavian river, and nine more were also sunk near the Tangarang river. Between the Batavian and Tangarang rivers, the land was rent and divided asunder, with great clefts more than a foot wide.†

18. On the 20th of November, 1720, a subterraneous fire burst out of the sea near Tercera, one of the Azores, which threw up such a vast quantity of stones, &c. in the space of thirty days, as formed an island about two leagues in diameter and nearly circular. Prodigious quantities of pumice stone, and half broiled fish, were found floating on the sea for many leagues round the island.‡

19. In the year 1746, Calloa, a considerable garrison town and sea-port in Peru, containing 5000 inhabitants, was violently shaken by an earthquake on the 28th of October; and the people had no sooner begun to recover from the terror occasioned by the dreadful convulsion, than the sea rolled in upon them in mountainous waves, and destroyed the whole town. The elevation of this extraordinary tide was such as conveyed ships of burden over the garrison walls, the towers, and the town. The town was razed to the ground, and so completely covered with sand, gravel, &c. that not a vestige of it remained.§

20. Previous to an eruption of Vesuvius, the earth trembles, and subterraneous explosions are heard; the sea likewise retires from the adjacent shore, till the mountain is burst open, then returns with impetuosity and overflows its usual boundary. These undulations of the sea are not peculiar to Vesuvius; the earthquake which destroyed Lisbon, on the first of November, 1755, was preceded by a rumbling noise, which increased to such a degree as to equal the explosion of the loudest cannon. About an hour after these shocks, the sea was observed from the high grounds to come rushing towards the city like a torrent, though against the wind and tide; it rose forty feet higher than was ever known, and suddenly subsided. At Rotterdam, the branches or chandeliers in a church were observed to oscillate like a pendulum: and we are told it is no uncommon thing to see the surface of the

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* Lowthorp's Abridg. Phil. Trans. vol. ii. pp. 408, 409.
† Ibid. vol. ii. p. 419.
‡ Eames' Abridg. Phil. Trans. vol. vi. part ii. p. 203.
§ Osborne's Relation of Earthquakes.

earth undulate as the waves of the sea at the time of these dreadful convulsions of nature.*

21. The last eruption of Vesuvius happened in July 1794, being the most violent and destructive of any mentioned in history, except those in 79, and 1631. The lava covered and totally destroyed 5000 acres of rich vineyards, and cultivated lands; and overwhelmed the town of Torre-del-Greco; the inhabitants, amounting to 18,000, fortunately escaped; and the town is now rebuilding on the lava that covers their former habitations. By this eruption the top of the mountain fell in, and the mouth of Vesuvius is now little short of two miles in circumference.

Earthquakes are generally supposed to be caused by nitrous and sulphureous vapours, inclosed in the bowels of the earth, which by some accident take fire where there is little or no vent. These vapours may take fire by fermentation,† or by the accidental falling of rocks and stones in hollow places of the earth, and striking against each other. When the matters which form subterraneous fires ferment, heat, and inflame, the fire makes an effort on every side, and if it does not find a natural vent, it raises the earth and forms a passage by throwing it up, producing a volcano. If the quantity of substances which take fire be not considerable, an earthquake may ensue without a volcano being formed. The air produced and rarefied by the subterraneous fire, may also find small vents by which it may escape, and in this case there will only be a shock, without any eruption or volcano. Again, all inflammable substances, capable of explosion, produce, by inflammation, a great quantity of air and vapour, and such air will necessarily be in a state of very great rarefaction: when it is compressed in a small space, like that of a cavern, it will not shake the earth immediately above, but will search for passages in order to make its escape, and will proceed through the several interstices between the different strata, or through any channel or cavern which may afford it a passage. This subterraneous air or vapour will produce in its passage a noise and motion proportionable to its force and the resistance it meets with: these effects will continue till it finds a vent, perhaps in the sea, or till it has diminished its force by expansion.

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* See the Phil. Trans. respecting the earthquake on the first of November, 1755, vol. xlix. part I.

† An equal quantity of sulphur and the filings of iron (about 10 or 15 lb.) worked into a paste with water, and buried in the ground, will burst into a flame in eight or ten hours, and cause the earth round it to tremble.

Mr. Whitehurst imagines, that fire and water are the principal agents employed in these dreadful operations of nature[*] and that the undulations of the sea and the earth, and the oscillation of pendulous bodies, are phenomena which arise from the expansive force of steam, generated in the internal parts of the earth by means of subterraneous fires: the force of steam being twenty-eight times[†] greater than that of gunpowder, viz. as 14,000 is to 500.[‡]

It is evident that there is a great quantity of steam generated in the earth, especially in the neighbourhood of volcanoes, from the frequent eruptions of boiling water and steam, in various parts of the world. Dr. Uno Von Troil, in his Letters on Iceland, has recorded many curious instances. "One sees here," says he, "within the circumference of half a mile, or three English miles, 40 or 50 boiling springs together; in some the water is perfectly clear, in others thick and clayey: in some, where it passes through a fine ochre, it is tinged red as scarlet: and in others, where it flows over a paler clay, it is white as milk." The water spouts up from some of these springs continually, from others only at intervals. The aperture through which the water rose in the largest spring was nineteen feet in diameter, and the greatest height to which it threw a column of water was ninety-two feet. Previous to this eruption a subterraneous noise was frequently heard, like the explosion of cannon; and several stones, which were thrown into the aperture during the eruption, returned with the spouting water.

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[*] M. Dolomieu seems to be of the same opinion.

[†] The force of steam is a function of its temperature, and therefore cannot be compared to force of gunpowder unless the temperature of the steam be given: according to *Robins*, the force of inflamed gunpowder is equal to the pressure of 1000 atmospheres; but by the experiments and calculations of Dr. Hutton, the force of gunpowder is much greater and is nearly equal to the pressure of 2000 atmospheres.

[‡] Inquiry into the Original State and Formation of the Earth, chap. xi. page 112.

## CHAPTER VIII.

### *Of the Atmosphere, Air, Winds, and Hurricanes.*

THE earth is surrounded by a thin fluid mass of matter, called the atmosphere: this matter gravitates towards the earth, revolves with it in its diurnal motion, and goes round the sun with it every year. Were it not for the atmosphere, which abounds with particles capable of reflecting light in all directions, only that part of the heavens would appear bright in which the sun is situated;* and the stars and planets would be visible at mid-day,† but, by means of an atmosphere, we enjoy the sun's light (reflected from the aërial particles contained in the atmosphere) for some time before he rises and after he sets; for, on the 21st of June, at London, the APPARENT day is 9 m. 16 sec. longer than the astronomical day.‡ This invisible fluid extends to an unknown height: but if, as astronomers generally estimate, the sun begins to enlighten the atmosphere in the morning when he comes within 18 degrees of the horizon of any place, and ceases to enlighten it when he is again depressed more than 18 degrees below the horizon in the evening, the height of the atmosphere may easily be calculated to be nearly 50 miles.§ Notwithstanding this great height of the atmosphere, it is seldom sufficiently dense at two miles high to bear up the clouds; it becomes more thin and rare the higher we ascend. This fluid body is extremely light, being, at a mean density, 816 times lighter than water;* it is likewise very elastic, as the least motion excited in it is propagated to a great distance: it is invisible, for we are only sensible of its existence from the effects it produces. It is capable of being compressed into a much less space than what it naturally possesses, though it cannot be congealed or fixed as other fluids may; for no degree of cold has ever been able to destroy its fluidity. It is of different density in every part upwards from the earth's surface, decreasing in its weight the higher it rises, and consequently must also decrease in density. The weight or pressure of the atmosphere upon any portion of the earth's surface is equal to the weight of a column of mercury which will cover the same surface, and whose height is from 28 to 31 inches: this is proved by experiment on the barometer, which seldom exceeds the limits above mentioned. Now, if we estimate the diameter of the earth at 7964† miles, the mean height of the barometer at 29½ inches, and a cubic foot of mercury to weigh 13500 ounces avoirdupois, the whole weight of the atmosphere will be 11522211494201773089 lbs. avoirdupois, and its pressure upon a square inch of the earth's surface 14⅖ lbs.

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* Dr. Keill, Lect. 20.

† M. de Saussure, when on the top of Mont Blanc, which is elevated 5101 yards above the level of the sea, and where consequently the atmosphere must be more rare than ours, says, that the moon shone with the brightest splendour in the midst of a sky as black as ebony; while Jupiter, rayed like the sun, rose from behind the mountains in the east. *Append. vol.* 74, *Monthly Review.*

‡ See *Keith's* Trigonometry, fourth edition, page 302.

§ Let A *r* B (*Plate* III. *Fig.* 5.) represent the horizon of an observer at A; S *r* a ray of light falling upon the atmosphere at *r*, and making an angle S *r* B of 18 degrees with the horizon (the sun being supposed to have that depression) the angle S *r* A will then be 162 degrees. From the centre O of the earth draw O *r*, and it will be perpendicular to the reflecting particles at *r*; and, by the principles of optics, it will likewise bisect the angle S *r* A. In the right angled triangle O A *r*, the angle O *r* A=81°, A O=(3982) miles, the radius of the earth. Hence, by trigonometry,

Sine of O *r* A, 81° —— 9.9946199
Is to A O, (3982) —— (3.6001013)
As radius, sine of 90° —— 10.0000000
Is to O *r* (431.76) —— (3.6054814)

Now, if from O *r*=[4031.6,) there be taken O V=O A=(3982,) the remainder V *r*=(49 6) miles is the height of the atmosphere.

The atmosphere is the common receptacle of all the effluvia or vapours arising from different bodies, *viz.* of the steam or smoke of things melted or burnt; of the fogs or vapours proceeding from damp, watery places; of steams arising from the perspiration of whatever enjoys animal or vegetable life, and of their putrescence when deprived of it; also of the effluvia proceeding from sulphureous, nitrous, acid, and alkaline bodies, &c. which ascend to greater or less heights according to their specific gravity. Hence the difficulty of determining the true composition of the atmosphere. Chemical writers,‡ however, have endeavoured to show that it consists *chiefly* of three distinct elastic fluids, united together by chemical affinity; namely, air, vapour, or water, and carbonic acid gas:* differing in their proportion at different times and in different places; but the average proportions of each, supposing the whole atmosphere to be divided into 100 equal parts, is given by Dr. Thomson as follows:

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* Dr. Thomson's Chemistry, vol. iv. page 7, edition of 1810.

† The diameter of the earth in inches will be 504599040; and the diameter with the atmosphere 504599099 inches, the difference between the cubes of these diameters multiplied by ·5236 gives 2359748914012523l287-3564 cubic inches in the atmosphere. Now, if 1728 cubic inches weigh 13500 ounces, as stated by Dr. Thomson, page 6, vol. iv. of his Chemistry, the weight of the atmosphere will be determined as above. If the square of the diameter 504599040 be multiplied by 3.1416, the product will give the superficies of the earth, = 799914792576284098.56 square inches; and if the weight of the atmosphere be divided by these superficies, the quotient will be 14.4 lbs. = 14 2-5 lbs., the pressure of the atmosphere on every square inch of the earth's surface. The pressure of the atmosphere on a square inch of surface, may likewise be found by experiments made with the air-pump, or by weighing a column of mercury whose base is one inch square, and height 29½ inches.

‡ Dr. Thomson's Chemistry, page 34, vol. iv. edition of 1810.

$98\frac{9}{10}$ air,
1 vapour or water,
$\frac{1}{10}$ carbonic acid.

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Hence it appears, that the foreign bodies which are mixed or united with the air in the atmosphere are so minute in quantity, when compared with it, that they have no very sensible influence on its general properties; wherefore, in describing the mechanical properties of the air, in the succeeding parts of this chapter, no attention is paid to its *component* parts in a chemical point of view; but wherever the word *air* occurs, common or atmospheric air is always meant. It may, however, be proper to remark here, that from various† experiments, chemists have inferred that if atmospheric air be divided into 100 parts, 21 of those parts will be *vital* air, and 79 *poisonous;* hence the vital air does not compose one-third of the atmosphere.

Air is not only the support of animal and vegetable life, but it is the vehicle of sound; and this arises from its elasticity: for a body being struck vibrates, and communicates a tremulous motion to the air: this motion acts upon the cartilaginous portion of the ear, where there are several eminences and concavities adapted to convey it into the auditory passage, where it strikes on the membrana tympani, or drum of the ear, and produces the sense of hearing.

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* *Gas* is a term applied by chemists to all permanently elastic fluids, except common air; and *carbonic acid* gas is what was formerly called *fixed air*, or such as extinguishes flame, and destroys animal life.

† Dr. Thomson, vol. iv. page 20, of his Chemistry, says, "Whatever method is employed to abstract oxygen from air, the result is uniform. They all indicate that common air consists very nearly of 21 parts of oxygen and 79 of azote."

21 oxygen gas (viz. *vital* air.)
79 azotic gas (viz. *poisonous* air.)

100

From the fluid state of the atmosphere, its great subtility and elasticity, it is susceptible of the smallest motion that can be excited in it; hence it is subject to the disturbing forces of the moon and the sun; and tides will be generated in the atmosphere similar to the tides in the ocean. By the continual motion of the air, noxious vapours, which are destructive to health, are in some measure dispersed; so that the air, like the sea, is kept from putrefaction by winds and tides.

Air may be vitiated, by remaining closely pent up in any place for a considerable length of time; and, when it has lost its vivifying spirit, it is called damp or fixed air, not only because it is filled with humid or moist vapours, but because it deadens fire, extinguishes flame, and destroys life.

If part of the vivifying spirit of air, in any country, begins to putrefy, the inhabitants of that country will be subject to an epidemical disease, which will continue until the putrefaction is over: and as the putrefying spirit occasions this disease, so, if the diseased body contribute towards the putrefying of the air, then the disease will not only be epidemical, but pestilential and contagious.

The air will press upon the surfaces of all fluids, with any force, without passing through them or entering into them; so that the sofest bodies sustain this pressure without suffering any change in their figure, and the most brittle bodies bear it without being broken. Thus the weight of the atmosphere presses upon the surface of water, and forces it up into the barrel of a pump. It likewise keeps mercury suspended at such a height, that its weight is equal to the pressure, and yet it never forces itself through the mercury into the vacum above.

Another property of the air is, that it is expanded by heat, and condensed or contracted by cold: hence the fire rarefying the air in the chimneys, causes it to ascend the funnels; while the air in the room, by the pressure of the atmosphere, is forced to supply the vacancy, and rushes into the chimney in a constant torrent, bearing the smoke into the higher regions of the atmosphere. In large cities, in the winter, where there are many fires, people, and animals, the air is considerably more rarefied than in the adjoining country; for which reason, continual currents of colder air rush in at all the exterior streets, bearing up the attenuated and contaminated air above the tops of the houses and the highest buildings, and supplying their place with air of a more salubrious quality. The more extensive winds owe their origin to the heat of the sun; this heat acting upon some part of the air causes it to expand, and become lighter, and consequently it must ascend; while the air adjoining, which is more dense and heavy, will press forward towards the place where it is rarefied. Upon this principle, we can easily account for the trade-winds, which blow constantly from east to west about the equator; for when the sun shines perpendicularly on any part of the earth, it will heat and rarefy the air in that part, and cause it to ascend; while the adjacent air will rush in to supply its place, and consequently will cause a stream or current of air to flow from all parts towards that which is the most heated by the sun. But as the sun, with respect to the earth, moves from east to west, the common course of the air will be from east to west; and therefore at or near the equator, where the mean heat of the earth is the greatest, the wind will blow continually from the east; but on the north side of the equator it will decline a little to the north; and, on the south side of the equator it will decline to the south. If the earth were covered with water, the motion of the wind would follow the apparent motion of the sun, in the same manner as the motion of the water would follow the motion of the moon; but, as the regular course of the tides is changed by the obstruction of continents, islands, &c. so the regular course of the winds is changed by high mountains, by the declination of the sun towards the north and south, by burning sands which retain the solar heat to an incredible degree, by the falling of great quantities of rain, which causes a suden condensation or contraction of the air, by exhalations that rise out of the earth at certain times and places, and from various other causes. Thus, according to Dr. Halley, between the 3d and 10th degrees of south latitude, the south-east trade-wind continues from April to October; during the rest of the year the wind blows from the north-west; but between Sumatra and New-Holland this *monsoon** blows from the south during our summer months: it changes about the end of September, and continues in the opposite direction till April.

Over the whole of the Indian Ocean, to the northward of the third degree of south latitude, the north-east trade-wind blows from October to April, and a south-west wind from April to October†. From Borneo, along the coast of Malacca, and as far as China, this monsoon in our summer blows nearly from the south, and in the winter from north by east. Near the coast of Africa, between Mosambique and Cape Guardafui, the winds are irregular during the whole year, owing to the different monsoons which surround that particular place. Monsoons are likewise regular in the Red Sea; between April and October they blow from the north-west, and during the other months from the south-east, keeping constantly parallel to the Arabian coast.*

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* The regular winds in the Indian seas are called *monsoons*, from the Malay word *moosin*, which signifies "a season." Forest's Voyage, page 95.

† The student will find these winds represented on Adams' globes, by arrows having the barbed points flying in the direction of the wind, as if shot from a bow; and, where the winds are variable, these arrows seem to be flying in all directions.

On the coast of Brazil, between Cape St. Augustine and the island of St. Catherine, from September to April the wind blows from the east or north-east; and from April to September it blows from the south-west; so that monsoons are not altogether confined to the Indian Ocean.

On the coast of Africa, from Cape Bajador, opposite to the Canary Islands, to Cape Verd, the winds are generally north-west; and from hence to the island of St. Thomas, near the equator, they blow almost perpendicular to the shore.

In all maritime countries of any considerable extent, between the tropics, the wind blows during a certain number of hours from the sea, and during a certain number from the land; these winds are called sea and land breezes. During the day, the air above the land is hotter and more rare than that above the sea; the sea air therefore flows in upon the land, and supplies the place of the rarefied air, which is made to float higher in the atmosphere; as the sun descends, the rarefaction of the land air is diminished, and an equilibrium is restored. As the night approaches, the denser air of the hills and mountains (for where there are no hills, there are no sea and land breezes) falls down upon the plains, and pressing upon the air of the sea, which has now become comparatively lighter than the land air, causes the land breeze.

The Cape of Good Hope is famous for its tempests, and the singular cloud which produces them: this cloud appears at first only like a small round spot in the sky, called by the sailors the Ox's Eye, and which probably appears so minute from its exceedingly great height.

In Natolia, a small cloud is often seen, resembling that at the Cape of Good Hope, and from this cloud a terrible wind† issues, which produces similar effects. In the sea between Africa and America, especially at the equator and in the neighbouring parts, tempests of this kind very often arise, and are generally announced by small black clouds. The first blast which proceeds from these clouds is furious, and would sink ships in the open sea, if the sailors did not take the precaution to furl their sails. These tempests seem to arise from a sudden rarefaction of the air, which produces a kind of vacuum, and the cold dense air rushing in to supply the place.

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* Bruce's Travels, vol. i. chap. iv.

† This wind seems to be described by St. Paul, in the 27th chapter of the Acts, by the name of the Euroclydon.

Hurricanes, which arise from similar causes, have a whirling motion which nothing can resist. A calm generally precedes these horrible tempests, and the sea then appears like a piece of glass; but, in an instant, the fury of the winds raises the waves to an enormous height. When from a sudden rarefaction, or any other cause, contrary currents of air meet in the same point, a whirlwind is produced.

The force of the wind upon a square foot of surface is nearly as the square of the velocity; that is, if on a square board of one foot in surface, exposed to a wind, there be a pressure of one pound, another wind, with double the velocity, will press the board with a force of four pounds, &c. The following table, extracted from the Philosophical Transactions, shows the velocity and pressure of the winds, according to their different appellations.

| Velocity of the wind. | | Perpendicular force on one square foot in pounds avoirdupois. | Common appellations of the winds. |
|---|---|---|---|
| Miles in one hour. | Feet in one second. | | |
| 1 | 1.47 | .005 | Hardly perceptible. |
| 2 | 2.93 | .020 | Just perceptible. |
| 3 | 4.40 | .044 | |
| 4 | 5.87 | .079 | Gentle pleasant wind. |
| 5 | 7.33 | .123 | |
| 10 | 14.67 | .492 | Pleasant brisk gale. |
| 15 | 22.00 | 1.107 | |
| 20 | 29.34 | 1.968 | Very brisk. |
| 25 | 36.67 | 3.075 | |
| 30 | 44.01 | 4.429 | High winds. |
| 35 | 51.34 | 6.027 | |
| 40 | 58.68 | 7.873 | Very high. |
| 45 | 66.01 | 9.963 | |
| 50 | 73.35 | 12.300 | A storm or tempest. |
| 60 | 88.02 | 17.715 | A great storm. |
| 80 | 117.36 | 31.490 | A hurricane. |
| 100 | 146.70 | 49.200 | A hurricane that tears up trees, and carries buildings, &c. before it. |

# CHAPTER IX.

## *Of Vapours, Fogs and Mists, Clouds, Dew and Hoar Frost, Rain, Snow and Hail, Thunder and Lightning, Falling Stars, Ignus Fatuus, Aurora Borealis, and the Rainbow.*

1. VAPOURS are composed of aqueous or watery particles, separated from the surface of the water or moist earth by the action of the sun's heat; whereby they are so rarefied and separated from each other, as to become specifically lighter than the air, and consequently they rise and float in the atmosphere.

2. FOGS AND MISTS. Fogs are a collection of vapours which chiefly rise from fenny, moist places, and become more visible as the light of the day decreases. If these vapours be not dispersed, but unite with those that rise from water, as from rivers, lakes, &c. so as to fill the air in general, they are called mists.

3. CLOUDS are generally supposed to consists of vapours exhaled from the sea and land.* These vapours ascend till they are of the same specific gravity as the surrounding air; here they coalesce, and by their union become more dense and weighty. The more thin and rare the clouds are, the higher they soar, but their height seldom, if ever, exceeds two miles. The generality of clouds are suspended at the height of about a mile; sometimes, when the clouds are highly electrified, their height is not above seven or eight hundred yards. The wonderful variety in the colours of the clouds is owing to their particular situation to the sun, and the different reflections of his light. The various figure of the clouds probably proceeds from their loose and voluble texture, revolving in any form, according to the different force of the winds, or from the electricity contained in them.

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* Dr. Thomson, in vol. iv. of his Chemistry, page 79, &c. edition of 1810, says, it is remarkable that, though the greatest quantity of vapours exist in the lower strata of the atmosphere, clouds never begin to form there, but always at some considerable height. The heat of the clouds is sometimes greater than that of the surrounding air. The formation of clouds and rain is neither owing to the saturation of the atmosphere, nor the diminution of heat, nor the mixture of airs of different temperatures. Evaporation often goes on for a month together in hot weather, especially in the torrid zone, without any rain. The water can neither remain in the atmosphere, nor pass through it, in a state of vapour: What then becomes of the vapour after it enters the atmosphere? what makes it lay aside the new form which it must have assumed, and return again to its state of vapour, and fall down in rain? Till these questions are experimentally answered, Dr. Thomson concludes, that the formation of clouds and rain cannot be accurately accounted for.

The general colour of the sky is blue, and this is occasioned by the vapours which are always mixed with the air, and which have the property of reflecting the blue rays, more copiously than any other.[*]

4. **Dew.** When the earth has been heated in the day time by the sun, it will retain that heat for some time after the sun has set. The air being a less dense or less compact substance, will retain the heat for a less time: so that in the evening the surface of the earth will be warmer than the air about it, and consequently the vapours will continue to rise from the earth; but, as these vapours come immediately into a cool air, they will only rise to a small height; as the rarefied air in which they began to rise becomes condensed, the small particles of vapours will be brought nearer together. When many of these particles are united, they form dew; and, if this dew freeze, it will produce hoar-frost.

5. **Rain.** When the weight of the air is diminished, its density will likewike be diminished, and consequently the vapours that float in it will be less resisted, and begin to fall, and, as they begin to strike upon one another in falling, they will unite and form small drops. But when the small drops of which a cloud consisted are united into such large drops, that no part of the atmosphere is sufficiently dense to produce a resistance able to support them, they will then fall to the earth, and constitute what we call rain. If these drops be formed in the higher regions of the atmosphere, many of them will be united before they come to the ground, and the drops of rain will be very large.[†] The drops of rain increase so much both in bulk and motion, during their descent, that a bowl placed on the ground would receive, in a shower of rain, almost twice the quantity of water that a similar bowl would receive on a neighbouring high steeple.[‡] The mean annual quantity of rain is greatest at the equator, and decreases gradually as we approach the poles. Thus, at

| | Latitude. | Depth of rain. |
|---|---|---|
| [§]Grenada, West Indies, | 12° 0′ | 126 inches. |
| St. Domingo, Cape St. Francois | 19° 46′ | 120 |
| Calcutta | 22° 23′ | 81 |
| In England | 53° 0′ | 32 |
| Petersburgh | 59° 16′ | 16 |

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[*] Saussure, Voyage dans les Alpes, vol. iv. p. 288.

[†] Dr. Rutherford's Natural Philosophy, vol. ii. chap. 10. Signior Beccaria, whose observations on the general state of electricity in the atmosphere have been very accurate and extensive, ascribes the cause of rain, hail, snow, &c. &c. to the effect of a moderate electricity in the atmosphere.

[‡] Mr. Adam Walker's Familiar Philosophy, lect. v. page 215.

[§] Dr. Thomson's Chemistry, vol. iv. page 83, &c. edition of 1810.

On the contrary, the number of rainy days is smallest at the equator, and increases in proportion to the distance from it. The number of rainy days is often greater in winter than in summer; but the quantity of rain is greater in summer than in winter. More rain falls in mountainous countries than in plains. Among the Andes, it is said to rain almost perpetually, while in the plains of Peru and Egypt, it hardly ever rains at all. The mean annual quantity of rain for the whole globe is estimated by Dr. Thomson at 34 inches in depth; hence may be found the whole quantity of rain that falls in a year upon the whole surface of the earth and sea, in the same manner as the number of cubic inches were found in the atmosphere, in chapter VIII. of this work. The same author observes that, for every square inch of the earth's surface, about 41 cubic inches of water is annually evaporated; so that the average quantity of rain is considerably less than the average quantity of water evaporated.

6. SNOW AND HAIL. Snow consists of such vapours as are frozen while the particles are small; for, if these stick together after they are frozen, the mass that is formed out of them will be of a loose texture, and form little flakes or fleeces, of a white substance, somewhat heavier than the air, and therefore will descend in a slow and gentle manner through it. Hail, which is a more compact mass of frozen water, consists of such vapours as are united into drops, and are frozen while they are falling.*

7. THUNDER AND LIGHTNING. It has been already observed, that the atmosphere is the common receptacle of all the effluvia or vapours, arising from different bodies. Now, when the effluvia of sulphureous and nitrous† bodies meet each other in the air, there will be a strong conflict, or fermentation between them, which will sometimes be so great as to produce fire.‡ Then, if the effluvia be combustible, the fire will run from one part to another, just as the inflammable matter happens to lie. If the inflammable matter be thin and light, it will rise to the upper part of the atmosphere, where it will flash without doing any harm; but if it be dense, it will lie near the surface of the earth, where, taking fire, it will explode with a surprising force, and by its heat rarefy and drive away the air, kill men and cattle, split trees, walls, rocks, &c. and be accompanied with terrible claps of thun-

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* Rutherford's Philosophy, vol. ii. chap. 10.

† Gunpowder, the effects of which are similar to thunder and lightning, is composed of six parts of nitre, one part of sulphur, and one part of charcoal.

‡ Professor Winkler's Philosophy.

der. The effects of thunder and lightning are owing to the sudden and violent agitation the air is put into, together with the force of the explosion. Stones and bricks struck by lightning, are often found in a vitrified state. Signior Beccaria supposes that some stones in the earth, having been struck in this manner, gave rise to the vulgar opinion of the thunder-bolt. It is now generally admitted that lightning and the electrical fluid are the same.[*]

8. THE FALLING STARS, and other fiery meteors, which are frequently seen at a considerable height in the atmosphere, and which have received different names according to the variety of their figure and size, arise from the fermentation of the effluvia of acid and alkaline bodies, which float in the atmosphere. When the more subtile parts of the effluvia are burnt away, the viscous and earthy parts become too heavy for the air to support, and by their gravity fall to the earth.

The disappearance of fiery meteors is frequently accompanied by a loud explosion like a clap of thunder, and heavy stony bodies have been observed to fall from them to the earth. Dr. Thomson[†] has given a table of thirty-six showers of stones, with the places where they fell, the dates, and the testimonies annexed.[‡]

These stoney bodies, when found, are always hot, and their size differs from a few ounces to several tons. They are usually round, and always covered with a black crust. When broken, they appear of an ash grey colour, and of a granular texture, like coarse sand-stone. These substances are probably concretions actually formed in the atmosphere, but in what manner no rational account has yet been given. Some philosophers conjecture that meteoric stone are projected from the moon by volcanoes; the velocity necessary for this projection being only about 7000 feet per second, or a little more than thrice the greatest velocity of a cannon ball. Others imagine that these stones are small fragments of terrestrial comets, which sometimes pass through our atmosphere, and have their surfaces violently heated by the resistance of the air; in consequence of which small portions of the comet are detached from its surface, and precipitated to the earth.

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[*] Signior Beccaria, of Turin, observes that the atmosphere abounds with electricity; and if a cloud which is positively charged (viz. which has more than its natural share of electrical fluid) pass near another cloud which is negatively charged (viz. which has less than its natural share of electrical fluid), they will attract each other, and a quick deprivation of the electrical fluid will take place: the flash is called lightning, and the report thunder; (the ensuing rollings are only echoes from distant clouds;) the water, thus deprived of its usual support, falls down in impetuous torrents.

[†] Chemistry, edition of 1810, vol. iv. page 122.

[‡] In the first volume of the Edinburgh Philosophical Journal (1819) page 221, &c. is given an "account of meteoric stones, masses of iron, and showers of dust, *red* snow, and other substances, which have fallen from the heavens, from the earliest period down to 1819."

9. OF THE IGNIS FATUUS, commonly called *Will-with-a-Whisp* or *Jack-with-a-Lantern.* This meteor, like most others, has not failed to attract the attention of philosophical inquirers. Sir Isaac Newton, in his Optical Queries, calls it a vapour shining without heat. Various accounts of it may be seen in the Philosophical Transactions.* The most probable opinion is, that it consists of inflammable air,† or oleaginous matter, emitted from a putrefaction and decomposition of vegetable substances, in marshy grounds; which being kindled by some electric spark, or other cause unknown to us, will continue to burn or reflect a kind of thin flame in the dark, without any sensible degree of heat, till the matter which composes the vapour is consumed. This meteor never abounds on elevated grounds, because they do not sufficiently abound with moisture to produce the inflammable air, which is supposed to issue from bogs and marshy places. It is often observed flying by the sides of hedges, or following the course of rivers; the reason of which is obvious, for the current of air is greater in these places than elsewhere. These meteors are very common in Italy and in Spain. Dr. Shaw‡ has described a remarkable ignis fatuus, which he saw in the Holy Land, when the atmosphere was so uncommonly thick and hazy, that the dew on the horses' bridles was remarkably clammy and unctuous. This meteor was sometimes globular, then in the form of the flame of a candle, presently afterwards it spread itself so much as to involve the whole company in a pale harmless light, and then it would contract itself again, and suddenly disappear; but, in less than a minute, it would become visible as before, and running along from one place to another with a swift progressive motion, would again expand itself, and cover a considerable space of ground.

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* Mr. Ray and some others suppose it to be a collection of *glow-worms* flying together; but Dr. Derham refuted this opinion. No. 411.

† Inflammable air may be made thus: exhaust a receiver of the air-pump, let the air run into it through the flame of the oil of turpentine, then remove the cover of the receiver, and hold a lighted candle to the air, it will take fire, and burn quicker or slower according to the density of the oleaginous vapour.

‡ Shaw's Travels, p. 363.

10. Of the aurora borealis, or northern lights. There have been various opinions and conjectures respecting the cause and properties of these extraordinary phenomena;[*] and the most probable opinion is, that they arise from exhalations, and are produced by a combustion of inflammable air, caused by electricity. This inflammable air is generated particularly between the tropics, by many natural operations, such as the putrefaction of animal and vegetable substances, volcanoes, &c.; and being lighter than any other, ascends to the upper regions of the atmosphere, and, by the motion of the earth, is urged towards the poles; for it has been proved by experiments that whatever is lighter, or swims on a fluid which revolves on an axis, is urged towards the extreme points of that axis:[†] hence these inflammable particles continually accumulate at the poles, and by meeting with heterogeneous matter take fire, and cause those luminous appearances frequently seen towards the polar regions.[‡]

In high latitudes the Auroræ Boreales appear with the greatest lustre, and extend over the greatest part of the hemisphere, varying their colours from all the tints of yellow to the most obscure russet.[§] In the north-east parts of Siberia, Hudson's Bay, &c. they are attended by a continued hissing and cracking noise through the air, similar to that produced by fire-works.[||]

11. Of the rainbow. The rainbow is the most beautiful meteor with which we are acquainted: it is never seen but in rainy weather, where the sun illuminates the falling rain, and when the spectator turns his back to the sun. There are frequently two

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[*] Philosophical Transactions, Nos. 305, 310, 320, 347, 348, 349, 351, 352, 363, 365, 368, 376, 385, 395, 398, 399, 402, 410, 418, 431, and 433, &c.

[†] See Mr. Kirwan's account of the Aurora Borealis, Irish Phil. Transactions for 1788, page 70.

[‡] We have very few accounts of the Aurora Australis, or Southern Lights, owing perhaps to the want of observations in those remote parts of the globe, and a proper channel of information. Captain Cook, in his second voyage towards the south pole, says: "(February 17th, 1773:) We observed a beautiful phenomenon in the heavens, consisting of long columns of clear white light, shooting up from the heavens to the eastward, almost to the zenith, and gradually spreading over the whole southern part of the sky. Though these columns were in most respects similar to the Aurora Borealis, yet they seemed to differ from them in being always of a whitish colour. The stars were sometimes hid by, and faintly to be seen through, the substance of these Aurora Australes. The sky was generally clear when they appeared, and the air sharp and cold, the thermometer standing at the freezing point; the ship being in latitude 58° south.

[§] Dr. Rees' New Cyclopædia, word Aurora Borealis.

[||] Philosophical Transactions, vol. lxxiv. page 288.

bows seen, the interior and exterior bow. The interior bow is the brightest, being formed by the rays of light falling on the *upper parts* of the drops of rain; for a ray of light entering the upper part of a drop of rain, will, by refraction, be thrown upon the inner part of the spherical surface of that drop, whence it will be reflected to the lower part of the drop, where, undergoing a second refraction, it will be bent towards the eye of the spectator; hence the rays which fall upon the interior bow come to the eye after two refractions and one reflection, and the colours of this bow from the *upper part* are *red, orange, yellow, green, blue, indigo,* and *violet.* The exterior bow is formed by the rays of light falling on the *lower parts* of the drops of rain; these rays, like the former, undergo two refractions, *viz.* one when they enter the drops, and another when they emerge from the drops to the eye; but they suffer two or more reflections in the interior surface of the drops; hence the colours of these rays are not so strong and well defined as those in the interior bow, and appear in an inverted order, *viz.* from the *under part* they are *red, orange, yellow, green, blue, indigo,* and *violet.* To illustrate this by experiment, suspend a glass globe filled with water in the sunshine, turn your back to the sun, and view the globe at such a distance that the part of it the farthest from the sun may appear of a full red colour, then will the rays which come from the globe to the eye make an angle of 42 degrees with the sun's direct rays; and if the eye remain in the same position, and another person lower the glass globe gradually, the orange, yellow, green, &c. colours, will appear in succession, as in the interior bow. Again, if the glass globe be elevated, so that the side nearest to the sun may appear red, the rays which come from the globe to the eye will make an angle of about 50 degrees; then, if another person gradually raise the glass globe, while the spectator remains in the same position, the rays will successively change from red to orange, green, yellow, &c. as in the exterior bow. These observations being understood, let *d n e* (*Plate* IV. *Fig.* 1.) represent a drop of rain belonging to the interior bow, s *d* a ray of light falling on the *upper part* of the drop at *d;* instead of the ray continuing its direction towards F, it will be refracted or bent towards *n,* whence part of it (for some will pass through the drop) will be reflected to *e,* making the angle of incidence *d n k* equal to the angle of reflection *e n k;* instead of continuing its direction from *e* towards *f,* it will, by emerging out of the water into the air, be again refracted to the eye at o. But, as this ray of light consists of a pencil[*] of rays, some of which are more refrangible[†] than others, the violet, which is the most refrangible, will proceed towards B, and the red, which is the least refrangible, will proceed towards O. Now, if the eye of the spectator be so placed that the ray of light falling upon it has been once reflected, and twice refracted, so that O *e* shall make, with the solar ray, S *d*, an angle S *m* O of 42° 2′[‡], he will see the red ray in the direction O *e m;* and if the eye be raised to B, so that B *e* shall make, with the solar ray S *d*, an angle B F S of 40° 17′ the violet ray will be seen in the direction B *c* F; the red ray will appear the highest, the violet the lowest, and the rest in order according to their different refrangibility, as in the interior bow (*Fig.* 2. *Plate* IV.); for the drop of water descends from F to *e*. What has been observed of one drop of water, will be true in an infinite number of drops; hence the interior bow is composed of a circular arc, whose breadth F *e*, is proportioned to the difference between the least and most refrangible rays.

To explain the exterior bow, Let *c t n d* (*Plate* IV. *Fig.* 1.) represent a drop of rain, S *d* a ray of light falling upon the under part of it at *d;* instead of this ray continuing its direction towards *m*, it will be refracted to *n*, whence part of it will pass through the drop, and the rest will be reflected to *t;* at *t* a part of it will again pass through the drop, and the remainder will be reflected to C; then in emerging from the water into the air, instead of continuing the direction CZ, it will be refracted from C to the eye at O. But as this ray of light, like that in the interior bow, consists of a pencil of rays of different refrangibility, the red, which is the least refrangible, will proceed towards A; and the violet, which is the most refrangible, will proceed towards O. Now, if the eye of the spectator be so placed that the ray of light falling upon it has been twice reflected, and twice refracted, so that O *o* shall make with the solar ray S *o* an angle S *o* O of 54° 7′, he will see the violet ray in the direction of O *c v;* and if the eye be raised to A, so that A *o* shall make with the solar ray S *o* an angle S *o* A of 50° 57, the red ray will be seen in the direction A *c r;* the violet ray will appear the highest, and the red ray the lowest, and the rest in order according to their different refrangibility, as in the exterior bow (*Plate* IV. *fig* 2.) for the drop of water descends from H to *d.* The same observations apply to an infinite number of drops, as in the interior bow.

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[*] A pencil of rays is a portion of light of a conical form *diverging* or proceeding from a point; or tending to a point, in which case the rays are said to *converge*.

[†] Refrangibility of the rays of light is their tendency to deviate from their natural course. Those rays which deviate the most from their natural course, in passing out of one medium into another, are said to be the most refrangible; and those which deviate the least from their natural course are the least refrangible. Sir Isaac Newton, by experiment, found the red rays to be the least refrangible, and the violet rays the most; and those rays which are the least refrangible are likewise the least reflexible.

[‡] The sine of incidence and refraction of the least refrangible rays out of water into air, is as 3 to 4, or as 81 to 108; and the most refrangible, as 81 to 109. Emerson's Optics, p. 92—The same author, at page 237. prob. xxvi. of his Optics, by the method of fluxions or increments, and using the numbers above, finds that the angle which the emergent ray makes with the incident ray, in the interior bow, is 42° 2 for the red, and 40° 17′ for the violet; and for the exterior bow, these angles are 50° 57′, and 54° 7′. The investigations are here omitted, because they cannot be rendered intelligible to any persons but mathematicians.

Hence, if the sun were a point, the breadth of the exterior bow would be (54° 7′—50° 57′ =) 3° 10′, that of the interior bow (42° 2′—40° 17′=) 1° 45′, and the distance between them (50° 57′—42° 2′=) 8° 55′; but, as the mean diameter of the sun is about 32′ 2″, the breadths of the bows must be increased by this quantity, and their distances diminished; the breadth of the exterior bow will then be 3° 42′, that of the interior bow 2° 17′, and their distance 8° 23′. The greater semi-diameter of the interior bow will be (42° 2′ + 16′, the sun's semi-diameter =) 42° 18′, and the least semi-diameter of the exterior bow (50° 57′—16′ the sun's semi-diameter =) 50° 41′.

All rainbows are arcs of equal circles, and consequently are equally large, though we do not always see an equal quantity of them; for the eye of a spectator is the vertex of a cone, and its circular base is the rainbow, the semi-diameter of which (for the interior bow) is the fixed quantity 42° 18′, equal to an angle FOP; and as SF will in all situations be parallel to OP, and the angle SFO, equal to FOP, must be always equal to 42° 18′, it is evident that as S rises, F and P will sink; and when SF makes an angle of 42° 18′ with the horizon, OF will coincide with OQ, and the interior bow will vanish; hence the interior bow cannot be seen if the sun's altitude exced 42° 18′: again, as the point P rises, the point S will sink, and when OP coincides with OQ, SF will be parallel to the horizon, (*viz.* the sun will be rising or setting,) and the whole semi-diameter of the rainbow will appear, which is the greatest part of it that ever can be seen on level ground: hence half a rainbow is the most that can be seen in such a situation; but if the observer be on the top of a high mountain, such as the Andes, with his back to the sun, and if it rains in a valley before him, a whole rainbow may be seen, forming a complete circle. The above reasoning is equally applicable to the outer bow; hence, as the sun rises, the bows sink, and when its altitude exceeds 42° 18′, the interior bow cannot be seen, and, if it exceeds (54° 7′ + 16′ =) 54° 23′, the exterior bow cannot be seen.

# PART II.

## THE ELEMENTARY PRINCIPLES OF ASTRONOMY.

ASTRONOMY determines the altitudes, distances, magnitudes, and orbits of the heavenly bodies; describes their various apparent and real motions, their periodical revolutions, eclipses or occulations, and furnishes us with a rational account of the various phenomena of the Heavens.

## CHAPTER I.

### *The General Appearance of the Heavens.*

If, on a clear night, we stand facing the south, and observe the heavens, they will appear to undergo a continual change.* Some stars will be seen ascending from the east, or *rising;* others descending towards the west, or *setting*. In some intermediate point between the east and west, each star will reach to its greatest height, or, will *culminate*. The greatest heights of the several stars will be different, but these heights will all be attained when the stars have arrived at a point exactly half way between the east and the west, *viz.* at the south.

If we now turn our backs to the south, and observe the north, new phenomena will present themselves. Some stars will appear as before, rising, attaining their greatest heights, and setting; other stars will be seen, that never set, moving with different degrees of velocity; and some nearly stationary.

The stars which never set appear to revolve about one particular star, and to describe circles of greater or less circumferences, according to their distances from that star. The stationary star is called the *Polar* star, and the stars which revolve round it at small distances are called the *circumpolar* stars.

The polar star which appears in the heavens is not stationary, neither is it situated exactly in the pole, but about a degree and three quarters from it*; that is, from a point in which, if a star were situated, it would appear perfectly fixed.

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* Exposition du Système du Monde, p. 2.

The general appearance, therefore, of the starry heavens, is that of a vast concave sphere, turning round two imaginary fixed points diametrically opposite to each other, the one in the north, the other in the south, and this apparent revolution is performed in about 24 hours.

Almost all the stars in the heavens retain towards each other the same relative position, they neither approach towards, nor recede from each other, and are therefore called *fixed* stars. There are, however, other celestial bodies, having the appearance of stars, which continually change their places. These are called *planets*.

The two celestial bodies of the most interesting appearance, and which claim our greatest attention, are the sun and the moon. These vary their situations from day to day, in the heavens; sometimes they appear in the same point of the heavens, and at other times directly opposite to each other.

The moon changes her figure every month, in which time she makes a complete tour round the heavens; and though she appears to rise and set every day like the stars, and to move from east to west, yet her apparent motion is retarded, and when compared with any particular fixed star she seems to go backward or towards the east: that is, if on any night she be seen in conjunction with a particular fixed star, the next night she will appear about 13° to the eastward of that star, the succeeding night at the same hour she will appear 26° to the eastward of the star, and so on.

The common phenomena of the rising and setting of the stars, and their apparent revolution from east to west, are easily accounted for, on the simple hypothesis of the earth's revolution on its axis from west to east (See *Part* I. *Chap*. IV.); but the continual change of place which the sun, the moon, and the planets undergo, cannot be accounted for on the same hypothesis, nor on the supposition that the whole heavens revolve from east to west in 24 hours.

The sun, apparently, moves towards the stars, which set after him, and from those which set before him: that is, to a spectator in the northern hemisphere, facing the south, his apparent motion is from the right hand to the left.

The sun's apparent motion from west to east with respect to the fixed stars, will adequately explain why certain remarkable

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stars, and groups of stars called *constellations*, are seen in the south at different hours of the night during the year. For the hour depends entirely on the sun: it is noon when he is in the south. Stars which are directly opposite him are, therefore, by the rotation of the earth on its axis, brought to the meredian at midnight.

But the stars which are on the meredian at 12 o'clock one night cannot again be there at the same hour on the succeeding night; for the sun's place being removed a little to the east, the stars which were opposite to him before are now opposite to a part of the heavens a little to the westward of the sun, and therefore they will come to the meridian a little before midnight: and, on each succeeding night they will come to the meridian by greater intervals before midnight; so that, in the course of the year they are all successively in the south, though sometimes they are invisible on account of their nearness to the sun.

The moon also moves among the stars from the west towards the east, more rapidly than the sun appears to move: the apparent motion of the sun arises from the real motion of the earth in its orbit, which is at the rate of about *one* degree in a day, (*see Def.* 61, *note*, *page* 36,) whereas the motion of the moon is about *thirteen* degrees in a day (*see the note*, *page* 91). The planets also, if observed on succeeding nights, will appear to change their places amongst the fixed stars, though when viewed from the earth they will not always appear to move towards the east, but sometimes towards the *west*, and at other times, for several nights together they will appear *stationary*.

The apparent motion towards the west, and the stationary appearance, are merely optical and illusory, arising from the combination of the earth's motion with that of the planet. Viewed from the sun, the motion of the planets is always in the same direction, and they never appear to be stationary.

The *apparent* motion of the sun, and the *real* motion of the moon and the planets from *west* to *east*, must be combined with the diurnal motion of the earth on its axis from *east* to *west*. The apparent motion of the stars from *east* to *west* is so rapid when compared with the real motion of the planets from *west* to *east*, that the latter motion passes unnoticed by inattentive spectators.

## CHAPTER II.

### *Of the Situation of the principal Constellations, and the Manner of distinguishing them from each other.*

The stars, with respect to their apparent splendour, are divided into different classes, called *magnitudes*. The brightest are called stars of the first magnitude; the next to these in splendour, stars of the second magnitude, and so on to those which are just perceptible to the naked eye, and which are called stars of the sixth magnitude. Those which cannot be discerned without the assistance of a telescope, are called *Telescopic Stars*, and are divided into classes of the seventh, eighth, &c. magnitudes.

The ancients divided the stars into different groups called *constellations* (*see Def.* 91), and gave particular names to each, which names the greater part of them have hitherto retained. The *Pleiades* and *Orion* are mentioned in the sacred writings by *Job*, and *Homer* and *Hesiod* describe several constellations by names which are now in general use.

A knowledge of the principal constellations in the heavens will be an useful acquisition to the student, and this may be obtained by noting the time when they come to the meredian, that is, to the south.

There are few persons who are unacquainted with the seven (*six*) stars called the *Pleiades*, or the beautiful constellation of *Orion*.* The Pleiades come to the meridian of London about an hour before Aldebaran,† and Orion culminates an hour after that star; and, since the diurnal difference of time of a star's culminating is nearly equal to the diurnal difference of the sun's right ascension, viz. about four minutes; a star will rise, come to the meredian, and set, nearly four minutes earlier every day, or about two hours in a month.

The time of culminating of each of the zodiacal constellations is given in the following table, and likewise the semi-diurnal arc; by which the time of rising and setting may be ascertained sufficiently accurate for practice. In the succeeding description, the principal constellations which culminate with the zodiacal constellations are pointed out, and their relative positions with respect to each other are shown; so that the time of their coming to the meridian may be easily found for any given day in the year.

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* This constellation is delineated, agreeably to its appearance in the heavens, in plate V.

† The time of this star's culminating on the first day of every month, is given in the following table.

A Table of the time of the *culminating* of the Zodiacal Constellations on the first Day of every Month, and the Semi-diurnal Arc at London.—N.B. The time is reckoned from noon to noon.

| Zodiacal Constellations. | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | S. Diur. Arc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aries, *Arietis, a.* | 7¼ | 5 | 3¼ | 1¼ | 23½ | 21½ | 19 | 17 | 15 | 13¼ | 11½ | 9½ | 8¼ H. |
| Taurus, *Aldebaran, a.* | 9¾ | 7½ | 5¾ | 3¾ | 1¾ | 23¾ | 21¾ | 19¾ | 17½ | 16¾ | 14 | 11¾ | 7½ H. |
| Gemini, *Castor, a.* | 12½ | 10½ | 8¾ | 6¾ | 4¾ | 2¾ | 11¾ | 22½ | 20½ | 18¾ | 17 | 15 | 9¾ H. |
| Cancer, *Acubene, a.* | 14 | 11¾ | 10¼ | 8¼ | 6½ | 4¼ | 2 | 12 | 22 | 20¼ | 18½ | 16½ | 7¼ H. |
| Leo, *Cor Leonis, a.* | 15¼ | 13 | 11¼ | 9¼ | 7½ | 5½ | 3½ | 1¼ | 23¼ | 21½ | 19½ | 17½ | 7½ H. |
| Virgo, *Spica, a.* | 18½ | 16¼ | 14½ | 12½ | 10¾ | 8½ | 6½ | 4¾ | 2½ | 12¾ | 22¾ | 20[illegible] | 5¼ H. |
| Libra, —— *a.* | 19¾ | 17½ | 15¾ | 14 | 12¼ | 10 | 8 | 6 | 4¼ | 2¼ | 12¼ | 1[illegible]¼ | 4¾ H. |
| Scorpio, *Antares, a.* | 21½ | 19¼ | 17½ | 15½ | 13¾ | 11¾ | 9¾ | 7¾ | 5¾ | 3¾ | 2 | [illegible] | 3½ H. |
| Sagittarius, *Bow, δ.* | 23¼ | 21¼ | 19¼ | 17¼ | 15½ | 13½ | 11½ | 9½ | 7½ | 5½ | 2¾ | ¾ | 3 H. |
| Capricornus, *Horn, β.* | 1½ | 23 | 21¼ | 19¼ | 17½ | 15½ | 13½ | 11¼ | 9½ | 7½ | 5¾ | 3¾ | 4¾ H. |
| Aquarius, *R Should, a.* | 3¼ | 1 | 23¼ | 21¼ | 19¼ | 17¼ | 15¼ | 13¼ | 11¼ | 9½ | 7½ | 5½ | 5¾ H. |
| Pisces, String, *a.* | 7 | 4¾ | 3 | 1 | 23¼ | 21¼ | 18¾ | 16¾ | 14¾ | 13 | 11¼ | 9¼ | 6¼ H. |

*The constellations and principal stars (visible at London) which culminate with the zodiacal constellations are the following, counting from the horizon.*

1. With Aries (*a Arietis.*) The neck of Cetus, Triangulum, Almaac in Andromeda, the head of Perseus, and the feet of Cassiopeia.—Mencar in Cetus, Musca, the head of Medusa, the body of Perseus, and the tail of Camelopardalus, culminate three-quarters of an hour after Arietis.

2. With Taurus (*Aldebaran.*) Part of Eridanus and Camelopardalus.—*Algenib* in Perseus culminates an hour and a quarter before Aldebaran, the Pleiades three-quarters of an hour before it, Rigel in Orion, and Capella in Auriga, about half an hour after it.

3. With Gemini (*Castor.*) Canis Major, Monoceros, Canis Minor, and the Lynx.—Sirius culminates three-quarters of an hour before Castor, and Procyon about six minutes after Castor.

4. With Cancer (*Acubene.*) The head of Hydra, the tail of the Lynx, and the head of the Great Bear; none of which are of sufficient importance to attract the student's particular attention.

5. With Leo (*Regulus.*) Part of Hydra, Leo Minor, and the shoulder of the Bear. The pointers in the Great Bear come to the meridian (above the pole) an hour after Regulus.

6. With Virgo (*Spica.*) The middle star in the tail of the Great Bear.—Coma Berenices and Cor Caroli culminate an hour before Spica; and Arcturus in Boötes about an hour after Spica.

7. With Libra (*a* on the ecliptic.) The left leg and the head of Boötes.—The head of the serpent, and Corona Borealis culminate three-quarters of an hour after *a* in Libra.

8. With Scorpio (*Antares.*) The left arm of Serpentarius, and the club and body of Hercules.

9. With Sagittarius (*the star in the bow marked δ.*) Scutum Sobieski, Cerberus in the left hand of Hercules, the head and body of Draco, and the pole of the ecliptic.—Vega in Lyra culminates a quarter of an hour after δ in Sagittarius.

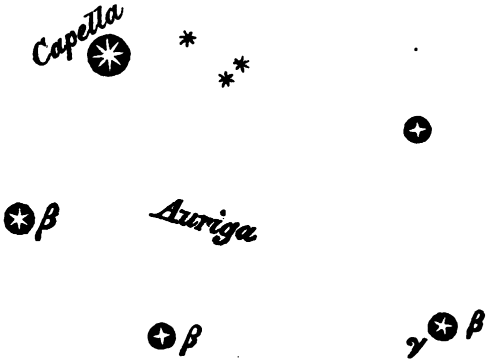
10. With Capricornus (*the star in the left horn marked β.*) The bow of Antinöus, Vulpecula et Anser, and the neck and body of Cygnus.—Altair in the Eagle comes to the meridian half an hour before β Capricornus, and the head of the Dolphin a quarter of an hour after it.

11. With Aquarius (*the star in the right shoulder marked a.*) The feet of Pegasus, the Lizard, and the head of Cepheus.—Fo-

malhout, in the Southern Fish, culminates three-quarters of an hour after *a* Aquarius, and Markab and Scheat in Pegasus an hour after it.

12. With Pisces (*the star in the string marked a.*) The head of Aries, Triangulum, Almaac in Andromeda, the sword of Perseus, and the feet of Cassiopeia.—*a* in the head of Andromeda culminates nearly two hours before *a* in Pisces, and Mirac in Andromea about an hour before it.

If the student observe the heavens in the month of *January*, about ten o'clock in the evening, when the stars are shining very bright, he will perceive towards the south the Pleiades, already mentioned; to the left hand of which, and a little lower, are Aldebaran, of a reddish colour, and the Hyades, in the Bull (*delineated in Plate* V.) Three stars in a row form the base of a triangle, of which triangle Aldebaran is situated at the vertex. Farther to the left hand, and a little higher than the Pleiades, is the remarkable constellation Auriga, which has exactly the appearance of the figure annexed.



The highest star towards the left hand is Capella, the star marked β and γ is situated in the Bull's north horn, and also in the right heel of Auriga.

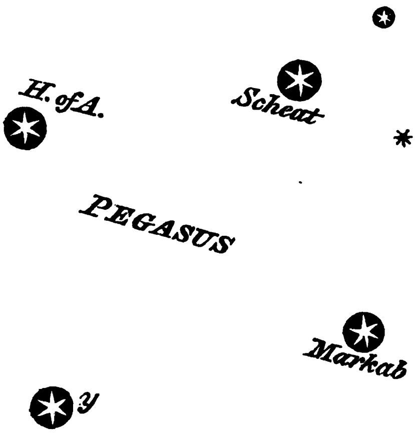
Imagine a line to be drawn from Capella through the star marked β γ towards the horizon, and it will pass through the middle of the constellation Orion. This constellation is delineated in Plate V., and is so brilliant and conspicuous in the heavens that its figure when compared with the plate will easily be known.

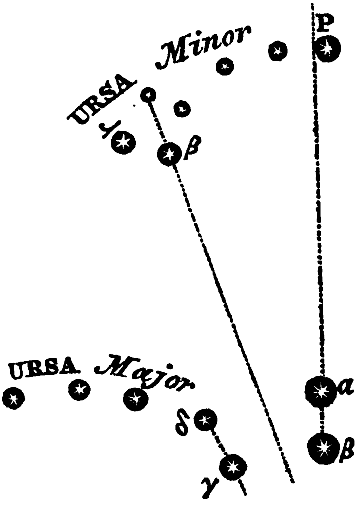
The three stars in a row form the Belt, and the largest star above the Belt towards the left-hand is Betelgeux, a star of the first magnitude in Orion's right shoulder. About 26° from Betelgeux, towards the left-hand is Procyon, a star between the first and second magnitudes, in the constellation Canis Minor. Between Betelgeux and Procyon, nearer to the horizon, is Sirius, easily distinguished by its scintillation and lustre; these three stars form an equilateral triangle.

To the left hand of Auriga, and at about the same distance from Capella as Aldebaran is, you will perceive Castor, a star of the first magnitude in Gemini; and near it towards the left-hand is Pollux. There are four stars in a line, about the half-way between Betelgeux and Castor, these are the four feet of Gemini. Castor culminates on the 1st of February, at half-past 10 o'clock. Sirius culminates three-quarters of an hour before Castor, and Procyon six minutes after.

To the right hand of Auriga, and above the Pleiades, in a line with Castor and Capella, is Algenib, a bright star in the breast of Perseus, and farther to the right is Almaac in Andromeda; these two stars, with Algol in the head of Medusa, form a triangle, of which Algol is the nearest to the Pleiades. Imagine a line to be drawn from the Pleiades, through Algol, and it will pass through Cassiopeia. This constellation is usually described by the figure of an inverted chair; but there are five bright stars in it, which resemble the capital letter W, indifferently made, much more than a chair.

To the right hand of the Pleiades, at a considerable distance, viz. about 22° is *a* Arietis, a star not very brilliant; a line drawn from the Pleiades through this star will pass through Markab in Pegasus. The constellation Pegasus is very remarkable, the three principal stars in it, with the head of Andromeda, form a large square, of which the four corner stars are all of the second magnitude. The highest star towards the right-hand is Scheat; it may be easily known by a kind of isosceles triangle, formed by three small stars, towards the right hand of it; one of these stars is a little above Scheat.





If the student stand facing the north, he will perceive Ursa Major, or the Great Bear, the most conspicuous constellation in the heavens. It is visible at all times when there are any stars to be seen. The annexed figure represents the Great Bear when below the pole. Of the seven brilliant stars in the Great Bear, those marked *a* and *β* are called the pointers, because they direct the eye to a bright star at P, situated about a degree and three-quarters from the pole of the world, which star, from its vicinity to that imaginary point, is named the *polar-star*.

Ursa Minor, or the Little Bear, has nearly the same shape as the Great Bear, but the situation is inverted, as represented by the figure, and the seven stars are not so bright as those in the Great Bear. An imaginary line drawn through the centre of the square of the Great Bear, perpendicular to the sides, will point out the bright star marked *β* in the square of the Little Bear.

These constellations will assist the student in acquiring a knowledge of the situation of others.

For instance, the tail of *Draco* lies between the polar star and the square of the Great Bear, and the figure extends in a serpentine direction towards the left-hand to a considerable distance, where it is terminated by four bright stars (in the head) forming nearly a square. An imaginary line drawn through δ and γ in Ursa Major, southward, will pass through the brightest star in Leo Minor, and through Regulus in Leo Major. Regulus is easily distinguished, being the southermost of four bright stars, resembling the letter Z inverted.

By the foregoing description, with the assistance of a celestial globe, it is presumed the learner may acquire a knowledge of the principal constellations which appear in the heavens in the winter. Those which present themselves in the summer are less conspicuous, but many of them may be distinguished by the following description.

If the student observe the heavens about ten o'clock in the evening, at the beginning of *May*, he will see the Great Bear near the zenith, above the pole. To the right-hand of the pointers in the Great Bear, and near the horizon, are Castor and Pollux, already described, and farther to the right-hand is Auriga. An imaginary line drawn through δ and γ, as noticed before, will pass through Leo Minor and through Regulus, and being continued in the same direction will pass through the heart of Hydra. To the right-hand of Cor Hydræ, near the horizon, a little more distant than Regulus, is Procyon in Canis Minor, and at about the same distance, on the left-hand, is Crater the Cup; beyond which, in the same diriction, is Corvus the Crow, being a kind of square formed by four principal stars. An imaginary line drawn through *a* in γ in the Great Bear, as a diagonal to the square, will pass through Cor Caroli near Coma Berenices, and through Spica Virginis. Spica Virginis, Arcturus in Boötes, and Deneb in the Lion's tail, form an equilateral triangle, in which Arcturus is the most elevated, and Deneb is situated towards the right-hand. A line connecting the first and third stars in the tail of the Great Bear will pass through Corona Borealis. This constellation is of an oval form, and is composed of eight stars, three of which are very bright, and appear close to each other. An imaginary line drawn from Arcturus through Corona Borealis, will pass through the body of Hercules, beyond which, in the same direction, is the bright star Vega in Lyra. Below Corona Borealis is Serpens, the Serpent; when these two constellations are on the meridian, which happens about three-quarters of an hour after the culminating of *a* in Libra, Arcturus will be on the right-hand and Vega on the left. Vega in Lyra, Altair in the Eagle, and the head of the Dolphin, form an isosceles triangle, of which Vega is at the vertex. Altair is easily known, being the middlemost of the three bright stars situated near to each other in a straight line. The Dolphin lies to the left-hand of the Eagle, and is composed of about five stars, four of which appear close together. Above the Dolphin, and to the left hand of Vega, is Cygnus, a remarkable constellation in the milky way, in the form of a large cross, below which is Pegasus already described.

In comparing the convex surface of the celestial globe with the apparent concavity of the heavens, the student will observe that the figures of the constellations are reversed; those which appear to the right-hand on the globe are to the left-hand in the heavens. The preceding account of their situations refers to the heavens.

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## CHAPTER III.

### *Of the Motion of the Fixed Stars by the Precession of the Equinoxes, by Aberration, and by the Nutation of the Earth's Axis; their proper Motions, Distance, variable Appearance, &c.*

It has already been shown (*Def.* 64.) that the intersection of the ecliptic with the equinoctial, has a retrograde motion of about 50¼ seconds in a year, and that a revolution of the equinoctial points will be completed in about 25,791 years. Now, since the equinoctial changes its position with respect to the ecliptic, its axis will also be changeable, and its poles, in the course of 25,791 years, will describe a circular path in the heavens. Hence the longitude, right ascension, and declination of every star will be variable, and consequently the pole of the equinoctial cannot always be directed to the same star. The star which at present is nearest to the north-pole of the equinoctial is *Alruccabah*, a star of the second magnitude in the tail of the Little Bear; it is about a degree and three quarters from the pole. The nearest approach of this star to the pole will be when its longitude is 90°; it will then be within half a degree of the pole, and this will happen in the year 2103.* its longitude in the year 1800 being 85° 46′ 10″. Since the fixed stars complete a revolution about the axis of the ecliptic in 25,791 years, any given star will perform half a revolution in 12,895½ years: therefore in 12,895 years after 2103, that is, in the year 14,998, the present polar star will be at its greatest distance from the pole of the equinoctial, which will be upwards of forty-five degrees. In the year of the world 1704, the star marked α in Dracon, was the polar star, being at that time within one-sixth of a degree of the pole of the equinoctial. This star lies half way between the middle star in the tail of the Great Bear and γ in the square of the Little Bear.

The *aberration* of the fixed stars is occasioned by the velocity of light, combined with that of the earth in its orbit (*see Def.* 121.), by which each star apparently decribes an ellipsis about its mean place in a year: the longer axis of this ellipsis is about 40″. The *Nutation* arises from the attraction of the moon upon the equatorial parts of the earth, by which the pole of the equinoctial describes an ellipsis about its mean place as a centre. This ellipsis is completed in a revolution of the moon's nodes, that is, in 18 years and 228 days: the greater axis being in the solstitial colure and equal to 19″.1, and the less axis in the equinoctial colure and equal to 14″.2.†

Dr. *Maskelyne* observes ‡ that many, if not all the fixed stars, have small motions among themselves, which are called their *proper motions;* the cause and laws of which are hid, for the present, in almost equal obscurity. By comparing his observations with others, he found the annual proper motion of the following stars, in right ascension, to be, of *Sirius,*—0″.63; of *Castor,*—0″.28; of *Procyon,*—0″.88; of *Pollux,*—0″.93; of *Regulus,*—0″.41; of *Arcturus,*—1″.4; of *α Aquilæ*+ 0″.57; and *Sirius* increased in north Polar distance +1″.20; *Arcturus* +2″.01.

The *magnitudes* of the fixed stars will probably for ever remain unknown; all that we can have any reason to expect, is a mere approximation founded on conjecture. From a comparison of the light afforded by a fixed star, and that of the sun, it has been concluded that the magnitudes of the stars do not differ materially from that of the sun. The different apparent magnitudes of the stars is supposed to arise from their different distances, for the young astronomer must not imagine that all the fixed stars are placed in a concave hemisphere, as they appear in the heavens, or on a convex surface, as they are represented on a celestial globe.

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* 50¼″: 1 year : : 90°—85° 46′ 10″ : 303 years, which, added to 1800, gives 2103.

† Dr. Mackay on the Longitude, vol. i. third edition, page 11.

‡ Explanation of the Tables, vol. i. of his *Observations.*

From a series of accurate observations byDr. Bradley on $\gamma$ *Draconis*, he inferred that its annual parallax did not amount to a single second; that is, the diameter of the earth's annual orbit, which is not less than 190 millions of miles, would not form an angle at this star of one second in magnitude; or, that it appeared in the same point of the heavens during the earth's annual course round the sun.

The same author calculates the distance of $\gamma$ *Draconis* from the earth to be 400,000 times that of the sun, or 38,000,000,000,000 miles: and the distance of the *nearest* fixed star from the earth to be 40,000 times the diameter of the earth's orbit, or 7,600,000,000,000 miles. These distances are so immensely great, that it is impossible for the fixed stars to shine by the light of the sun reflected from their surfaces: they must therefore be of the same nature with the sun, and like him shine by their own light.

The number of the fixed stars is almost infinite, though the number which may be seen by the naked eye in the whole heavens does not exceed, and perhaps falls short of 3000,* comprehending all the stars from the first to the sixth magnitude inclusive; but a good telescope, directed almost indifferently to any point in the heavens, discovers multitudes of stars invisible to the naked eye. That bright irregular zone, the milky way, has been very carefully examined by Dr. Herschel; who has, in the space of a quarter of an hour, seen 116,000† stars pass through the field of view of a telescope of only 15′ aperture.

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* By adding up the numbers of stars in the first column of the British Catalogue given at pages 27, 28, and 29, the sum will be found to be 3457. See page 26.

† *Vince's* Astronomy, or Philosophical Transactions for 1785, vol. lxxv. page 244. Dr. Herschel says, "in the most crowded part of the milky way I have had fields of view that contained no less than 588 stars, and these were continued for many minutes, so that in one quarter of an hour's time there passed no less than 116,000 stars through the field of view of my telescope.—The breadth of my sweep was 2° 26′, to which must be added 15′ for the two semi-diameters of the field. Then putting 161′=*a*, the number of fields in 15′ of time; 7854=*b*, the proportion of a circle to 1, its circumscribed square; $\phi$=sine of 74° 22′ the polar distance of the middle of the sweep reduced to the present time; and 588=*s*, the number of stars in a field of view, we have

$$\frac{a \phi s}{b} = 116076 \text{ stars."}$$

The fixed stars are the only marks by which astronomers are enabled to judge of the course of the moveable ones, because they do not vary their relative situations. Thus, in contemplating any number of fixed stars, which to our view form a triangle, a four-sided figure, or any other, we shall find that they always retain the same relative situation, and that they have had the same situation for some thousands of years, viz. from the earliest records of authentic history. But as there are few general rules without some exceptions, so this general inference is likewise subject to restrictions. Several stars, whose situations were formerly marked with precision, are no longer to be found; new ones have also been discovered, which were unknown to the ancients; while numbers seem gradually to vanish, and others appear to have a periodical increase and decrease of magnitude. Dr. Herschel, in the Philosophical Transactions for 1783, has given a large collection of stars which were formerly seen, but are now lost, together with a catalogue of variable stars, and of new stars.

The periodical variation of *Algol* or β *Persei*, is about two days 21 hours; its greatest brightness is of the second magnitude, and least of the fourth. It varies from the second magnitude to the fourth in about 3¼ hours, and back again in the same time, retaining its greatest brightness for the remainder of its period.

The fixed stars do not appear to be all regularly disseminated through the heavens, but the greater part of them are collected into clusters; and it requires a large magnifying power, with a great quantity of light, to distinguish separately the stars which compose these clusters. With a small magnifying power, and a small quantity of light, they only appear as minute whitish spots, like small light clouds, and thence are called *nebulæ*. Dr. Herschel has given a catalogue of 2000 *nebulæ*, which he has discovered, and is of opinion that the starry heavens are replete with these *nebulæ*. The largest *nebula* is the milky way, already noticed at page 53.

From an attentive examination of the stars with good telescopes, many which appear single to the naked eye, have been

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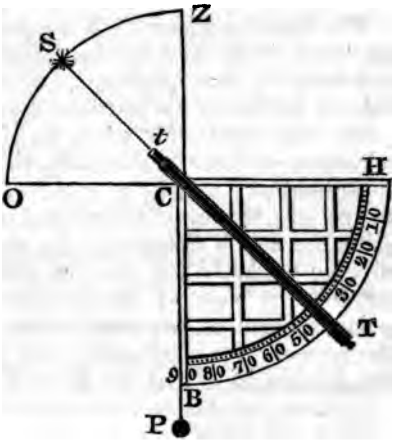
This calculation is founded upon a supposition that the stars were equally disseminated through the whole field of view of the telescope; and therefore can be considered only as an ingenious approximation to the truth.

found to consist of two, three, or more stars. Dr. Herschel, by the help of his improved telescopes, has discovered nearly 700 such stars. Thus *a Herculis*, δ *Lyræ*, *a Geminorum*, γ *Andromedæ*, μ *Herculis*, and many others, are double stars; υ *Lyræ*, is a triple star; and ε *Lyræ*, β *Lyræ*, λ *Orionis*, and ξ *Libræ*, are quadruple stars.*

# CHAPTER IV.

## *The Method of measuring the Altitudes, Zenith Distances, &c. of the Heavenly Bodies, including a Description of the Astronomical Quadrant, Circular Instrument, and Transit Instrument.*

It is of importance to the young astronomer to know in what manner the altitudes of the heavenly bodies are determined; for which reason the most simple instruments for that purpose are here described. This description, however, must be considered as contracted and imperfect, since the various adjustments of the instruments, and the manner of using them to advantage, can be acquired only by practice.



The astronomical quadrant is generally made of brass; the arc H B is divided into 90 equal parts, called degrees, and each degree is subdivided into smaller parts, according to the size of the instrument. T *t* is a telescope moveable about a centre, C. From the centre C is suspended a weight P hanging freely in the direction of gravity, or perpendicularly to the earth's surface, the line CP is called a plumb-line.

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* Vince's Astronomy, chap. xxiv.

Now, if the plane of the instrument, by proper adjustments, be made to coincide with the plane of the meridian of any place, and the plumb-line CP at the same time be made to hang exactly over the division marked 90; it is obvious, that if the telescope T *t* be directed towards the star S in the plane of the meridian, the number of degrees between H and T on the arc, will mark the star's altitude O S on the meridian, and the number of the degrees between T and B will mark its zenith distance S Z: for the imaginary quadrant O Z of the meridian is supposed to be similarly divided to the instrumental quadrant H B, and to contain 90 degrees between the horizon and the zenith. If the star be in the horizon at O, the telescope will coincide with H O or be parallel to it; if the star be in the zenith at Z, the telescope will coincide with the plumb-line CP. In the figure annexed the telescope is directed towards a star having about 40 degrees of altitude. The quadrant may be placed in the plane of any other vertical circle as well as in that which passes through the meridian, and then it will measure altitudes in that vertical circle.

When the quadrant is fixed against a vertical wall in the plane of the meridian, it is called a *mural* quadrant. Such are the quadrants in the Royal Observatory at Greenwich.

The astronomical instrument now generally used is an improvement upon the quadrant here described; and this improvement consists, chiefly, in putting together four quadrants, and thereby forming a circular instrument.

The figure in Plate VI, is a representation of a small model of the large circles used in observatories.* The vertical circle A B is formed by *four* quadrants, and the telescope C D is not moveable on the arc of the instrument as before, but is attached to the circle, and moves only when the circle itself moves. When the telescope is placed horizontally, viz. in the direction A B, the divisions marked *o* will be at Z and M. If the telescope be directed to any star, the arc of the circle from the telescope at C to M will show the zenith distance of the star, and the arc from M to the division marked *o* will show its altitude; if the instrument be situated in the plane of the meridian, it will show the altitude and polar distance of any star, or the star's declination; for, having the latitude of a place given, and the meridian altitude of a star, the declination of that star is readily determined.

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* This figure is copied from a *new*, portable, and useful instrument, made by Messrs. W. and S. Jones, of *Holborn*, who very kindly furnished the Author with a drawing of it, from which drawing the plate is engraven.

The vertical circle of the instrument here described is graduated as in the figure; at M is a Nonius scale, with a microscope, which reads off to one minute of a degree; the slow motion of the circle, for accuracy of observation, is produced by turning the screw at G.

The achromatic telescope C D is contrived by a reflecting eye-piece, to admit of observations conveniently to the zenith. The axis of the vertical circle reverses for the adjustment, and is made level by the small suspended spirit-level L. The wires of the telescope are illuminated at night by a small reflector placed in the inside of the axis, and the light is transmitted through the axis by means of a small lighted lamp occasionally attached to it.

The base of the instrument, which supports the vertical circle, has a horizontal motion, the slow motion of which is produced by turning the screw at O. By the motion of the horizontal circle the azimuths of the celestial objects are obtained, and this circle is placed truly horizontally by means of the two spirit-levels S, S; the screws at E, E, E, are for the purpose of fixing the base in its proper position.

When the vertical circle is truly placed in the plane of the meridian, the vertical wires of the telescope will answer the purpose of a *transit* instrument.

By the assistance of this instrument the altitude of the sun's centre may be observed from day to day, and this altitude will be found to vary continually by unequal differences: also the successive transits of the fixed stars over the meridian may be ascertained.

## CHAPTER V.

### *Of the Solar System.* (*Plate* II. *Fig.* 1.)

THE solar system is so called because the sun is supposed to be situated in a certain point termed the centre of the system, having all the planets revolving round him at different distances, and in different periods of time. This is likewise called the Copernican system.

## I. OF THE SUN.

The sun is situated near one of the foci of the orbits of all the planets, and revolves on its axis in 25 days 14 hours 4 minutes. This revolution is determined from the motion of the spots on its surface, which first make their appearance on the eastern extremity, and then by degrees come forwards towards the middle, and so pass on till they reach the western edge, and then disappear. When they have been absent for nearly the same period of time which they were visible, they appear again as at first, finishing their entire circuit in 27 days 12 hours 20 minutes.[*]

The sun is likewise agitated by a small motion round the centre of gravity of the solar system, occasioned by the various attractions of the surrounding planets; but, as this centre of gravity is generally within the body of the sun,[†] and can never be at the distance of more than the length of the solar diameter from the centre of that body, astronomers generally consider the sun as the centre of the system, round which all the planets revolve. As the sun revolves on its axis, his figure is supposed not to be strictly in the form of a globe, but a little flatted at the poles; and that his axis makes an angle of about eight degrees,[‡] with a perpendicular to the plane of the earth's orbit. As the sun's apparent diameter is greater in December than in June, it follows that the sun is nearer to the earth in our winter than it is in summer; for the apparent magnitude of a distant body diminishes as the distance increases. The mean apparent diameter of the sun is stated to be 32′ 2″; hence, taking the distance of the sun from the earth to be 95 millions of miles as before determined,[§] its real diameter will be 886149 miles; and as the magnitudes of all spherical bodies are as the cubes* of their diameters, the magnitude of the sun will be 1377613 times that of the earth; the diameter of the earth being only 7920 miles, the diameter of the sun is above one hundred and eleven times the diameter of the earth.

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[*] M. Cassini determined the time which the sun takes to revolve on its axis thus: the time in which a spot returns to the same situation on the sun's disc (determined from a series of accurate observations) is 27d. 12h. 20m.: now the mean motion of the earth in that time is 27° 7′ 8″: hence $360^{\circ} \times {}^{\circ}7' 8''$. : 27d. 12h. 20m. : : 360° : 25d. 14h. 4m., the time of rotation.

[†] Sir. I. Newton's Princip. Book iii. Prop. 11. & 12.

[‡] Walker's Familiar Philosophy, Lecture xi. page 516.

[§] The semi-diameter of the earth has been determined at page 76, in the note, to be 3982 miles; and the distance of the earth from the sun is 23882.84 semi-diameters of the earth. See the note, page 80. Now the apparent semi-diameter $mn$ of the sun (*Plate* IV. *Fig.* 3.) is measured by the angle $mon = 32' 2''$: hence the angle $omn =$ the angle $onm = \frac{180^{\circ} - 32' 2''}{2} = 89^{\circ} 43' 59''$; and on account of the distance of the sun from the earth, $om$, $oc$, and $on$ may be considered as equal. Hence,

## II. OF MERCURY ☿.

Mercury is the least of all the planets, whose magnitudes are accurately known, and the nearest to the sun. The inclination of its axis to the plane of its orbit, and the time it takes to revolve on its axis, are unknown; consequently the vicissitudes of its seasons, and the length of its day and night, are likewise unknown. Mercury is seen through a telescope sometimes in the form of a half-moon, and sometimes a little more or less than half its disc is seen; hence it is inferred, that he has the same phases as the moon, except that he never appears quite round, because his enlightened side is never turned directly towards us, unless when he is so near the sun as to become invisible, by reason of the splendour of the sun's rays.—The enlightened side of this planet being always towards the sun, and his never appearing round, are evident proofs that he shines not by his own light; for, if he did, he would constantly appear round. The best observations of this planet are those made when he is seen on the sun's disc, called his transit; for in his lower conjunction he sometimes passes before the sun, like a little spot, eclipsing a small part of the sun's body. The last transit of mercury was on the 22d of November, 1822; it was not visible at Greenwich. That node from which Mercury ascends northward above the ecliptic is in the fifteenth degree of Taurus†, and consequently the opposite or descending node is in the fifteenth degree of Scorpio. The sun is in the fifteenth degree of Taurus on the 6th of May, and in the fifteenth of Scorpio on the 7th of November; and when Mer-

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Sine *omn* 89° 43′ 59″ . . . . . . . . . . . 9.9999953
Is to 23882.84 semi-diameters : . . . . 4.3780860
As sine *m* o *n* 32′ 2″ . . . . . . . . . . . 7.9693152
Is to 222.5388 semi-diameters : . . . . 2.3474059

Now, 222.5388 × 3982=886149.5016 miles, the diameter of the sun, the cube of which divided by the cube of 7964, the diameter of the earth, gives 1377613 times the sun is larger than the earth.

* Euclid xii. and 18th.

† The place of Mercury's ascending node for 1750 was 15° 20′ 43″ in Taurus, and its variation in one hundred years is 1° 12′ 10″.—*Vince's Astronomy.*

cury comes to either of his nodes at his inferior conjunction (viz. when he is between the earth and the sun), he will pass over the sun's disc, if it happen on or near the days above mentioned; but in all other parts of his orbit, he goes either above or below the sun, and consequently his conjunctions are invisible.

Mercury performs his periodical revolution round the sun in 87 d. 23 h. 15 min. 43 sec.; his greatest elongation is 28° 20′; distance from the sun 36814721* miles; the eccentricity of his orbit is estimated at one-fifth of his mean distance from the sun; his apparent diameter 11″; hence his real diameter is 3108

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* According to *Laplace*, Mercury's sidereal period is 87.969258 days, and his mean distance from the sun is .387098, assuming the earth's distance as a standard and equal to 1.

The distance of Mercury, or any planet, from the sun, may be found by *Kepler's rule*. Thus, the square of the time which the earth takes to revolve round the sun, is to the cube of the mean distance of the earth from the sun, as the square of the time which any other planet takes to revolve round the sun, is to the cube of *its* mean distance; the cube-root of which will give the distance sought. Or, *which is shorter*, divide the square of the time in which any planet revolves round the sun, by the square of the time in which the earth revolves round the sun, the cube-root of the quotient will give the *relative distance* of the planet from the sun. This relative distance, multiplied by the mean distance of the earth from the sun, will give the mean distance of the planet from the sun.

*First for Mercury*. The earth revolves round the sun in 365 d. 5 h. 48 min. 48 sec.=31556928 sec. the square of which is 995839704797184, a constant divisor for all the planets, and 23882.84, the distance of the earth from the sun in semi-diameters (see page 80, note) will be a constant multiplier, .87 d. 23 h. 15 m. 43 sec.=7600543 sec. the square of which is 57768253894849. This square divided by the former, gives .0580096 nearly, the cube-root of which is .38710991, the distance of Mercury from the sun, supposing the distance of the earth from the sun to be an *unit*. .38710991 × 23882.84=9245.2841 distance of Mercury from the sun in semi-diameters of the earth; hence 9245.2841 × 3982, radius of the earth,=36814721 miles, the mean distance of Mercury from the sun.

The distance of the inferior planets from the sun may be found by their elongations. M. de la Lande has calculated that, when Mercury is in his aphelion, and the earth in its perigee, the greatest elongation of Mercury is 28° 20′; but when Mercury is in his perihelion, and the earth in its apogee, the greatest elongation is 17° 36′; the medium, therefore, is 22° 58′. Hence, in the triangle, SEV. (*Plate* II. *Fig* 2.) the angle SEV=22° 58′, the distance of the earth from the sun SE=23882.84 semi-diameters, and EVS is a right angle.

| | |
|---|---|
| Radius, sine of 90° .......... | 10.0000000 |
| Is to SE=23882.84 ........... | 4.3780860 |
| As sine of 22° 58′ ........... | 9.5912823 |
| Is to 9318.976 semi-diameters ..... | 3.9693683 |

Hence 9318976 × 3982=37108162 miles, the distance of Mercury from the sun by this method; but an error of a few seconds in the elongation will make a considerable difference.

miles ;* and his magnitude about one-sixteenth of the magnitude of the earth.

Mercury emits a bright white light; he appears a little after sun-set, and again a little before run-rise; but, on account of his nearness to the sun, and the smallness of his magnitude, he is seldom seen. The light and heat which this planet receives from the sun, is about seven times greater than the light and heat which the earth receives.† The orbit of Mercury makes an angle of seven degrees with the ecliptic, and he revolves round the sun at the rate of upwards of one hundred and nine thousand miles per hour.‡ The manner in which the earth revolves round the sun has already been explained at page 66, and as all the other planets move in a similar manner in elliptical orbits, having the sun in one of the foci, what has been observed respecting the earth will be equally applicable to all the planets.

## III. OF VENUS ♀.

Venus is the brightest, and, to all appearance, the largest of all the planets; her light is distinguished from that of the other planets by its brilliancy and whiteness, which are so considerable that, in a dusky place, she causes an object to cast a sensible shadow. Venus, when viewed through a telescope, appears to have all the phases of the moon, from the crescent to the enlightened hemisphere, though she is seldom seen perfectly round. Her illuminated part is constantly turned towards the sun; hence, the convex part of her cresent is turned towards the east when she is a morning star, and towards the west when she is an evening star; for when Venus is west of the sun, as seen from the earth, that is, when her longitude is less than the sun's longitude, she rises before him in the morning, and is then called a morning star; but when she is east of the sun, viz. when her longitude is greater than the sun's longitude, she shines in the evening after the sun sets, and is then called an evening star.

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* The mean distance of the earth from the sun is 23882.84 semi-diam., and Mercury's distance 9245.2841 semi-diam.: the difference is 14637.5559 semi-diam.: the distance of Mercury from the earth; and, as the magnitudes of all bodies vary *inversely* as their distances, we have by the rule-of-three inverse 14637.5559 : 11″ : : 23882.84 : 6.74179″, the apparent diameter of Mercury, at a distance from the earth equal to that of the sun. Now the mean apparent diameter of the sun is 32′ 2″, and its real diameter 886149 miles; hence 32′ 2″ : 886149 m. : : 6″.74179 : 3108 miles of the diameter of Mercury: and, if the cube of the diameter of the earth be divided by the cube of the diameter of Mercury, the quotient will be 16.8 times the magnitude of the earth exceeds that of Mercury.

The diameter of Mercury might have been found exactly in the same manner as the diameter of the sun was found in the note, page 140, using 11″ instead of 32′ 2″, and 14637.5559 semi-diam. instead of 23882.84 semi-diam.: the result of the operation in this case will be .78061 semi-diam. of the earth; hence .78061 × 3982 = 3108 miles the diameter of Mercury exactly as above. It has been remarked at page 80, that the apparent diameters of the planets are measured by a micrometer, said to be invented by *M. Azout*, a *Frenchman;* but it appears, from the Philosophical Transactions, that it was invented by *Mr. Gascoigne*, an *Englishman.*

† As the effects of light and heat are reciprocally proportional to the squares of the distances from the centre whence they are propagated, if you divide the square of the earth's distance from the sun, by the square of Mercury's distance from the sun, the quotient will show the comparative heat of Mercury to that of the earth.

‡ This is found in the same manner as for the earth in page 81. Thus, if you double the distance of any planet from the sun, then multiply by 355, and divide

Venus is a morning star, or appears west of the sun for about 290 days, and she is an evening star, or appears east of the sun for nearly the same length of time, though she performs her whole revolution round the sun in 224 days 16 hours 49 minutes 10 seconds. A very natural question here may be asked, viz. Why Venus appears a longer time to the eastward or westward of the sun than the whole time of her entire revolution round him? This is easily answered, by considering that, while Venus is going round the sun, the earth is going round him the same way, though slower than Venus, and therefore the relative motion of Venus is slower than her absolute motion.

Sometimes Venus is seen on the disc of the sun in the form of a dark round spot. These appearances happen but seldom, viz. they can happen only when Venus is between the earth and the sun, and when the earth is nearly in a line with one of the nodes of Venus.* The last transit of Venus was in 1769, and the two next transits, in succession, will fall on the 8th of December, 1874, and on the 7th of June, 2004. The time which this planet takes to revolve on its axis, and the inclination of its axis to the plane of its orbit, have been given by different astronomers;

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the last product by 113, you obtain the circumference of the planet's orbit in miles. This circumference, divided by the number of hours in the planet's year, will give the number of miles per hour which that planet travels round the sun: *a general rule for all the planets.* Hence,

The circumference of Mercury's orbit will be found to be 231313733.717 miles; then 87d. 23h. 15′ 43″: 231313733.717 miles : : 1 h. : 109561 miles Mercury travels *per* hour.

* The place of the ascending node of Venus for 1750 was 14° 26′ 18″ in Gemini, and its variation in 100 years is 51′ 40″. *Vince's Astronomy.*

but Dr. Herschel, from a long series of observations on this planet, published in the Philosophical Transactions for 1793, concludes, that the time of this planet's rotation on its axis is uncertain and that the position of its axis is equally uncertain; that its atmosphere is very considerable; that it has probably inequalities on its surface, yet he cannot discover any mountains. The apparent diameter of Venus is stated to be 58″.79; the eccentricity of her orbit 473100 miles;* her greatest elongation 47° 48′; her revolution round the sun is performed in 224 d. 16 h. 49 m. 10 sec.,† as before stated; and, if her apparent diameter be taken as above, her true diameter will be 7498 miles,‡ and her magnitude something less than that of the earth; likewise her distance from the sun will be found to be 68791752 miles.

The light and heat which this planet receives from the sun, are about double to what the earth§ receives. The orbit of Venus makes an angle of 3° 23′ 35″ with the ecliptic, and she revolves round the sun at the rate of upwards of eighty thousand miles per hour.* This planet, like Mercury, never departs from the sun; she is only visible a few hours in the morning before the sun rises, or in the evening after he sets; an evident proof that the orbits of these planets are contained within the orbit of the earth, otherwise they would be seen in opposition to the sun, or above the horizon at midnight.

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* For, according to M. de la Lande, if the mean distance of the earth be 100000, the eccentricity of Venus will be 498; hence, when the distance is 95 millions of miles, the eccentricity will be 473100 miles.

† The seconds in this time=19414150, the square of which is 376909220222500, this divided by 9958397047971 84 (*see the note, page* 142.) gives .3784838, &c. the cube root of which is .7233511; this, multiplied by 23882.84, produces 17275.678585 semi-diam. which, multiplied by 3982=68791752 miles, the distance of Venus from the sun.

According to *Laplace*, the sidereal revolution of Venus is 224.700824 days, and her mean distance from the sun is .723332.

M. de la Lande has found the greatest elongations of Venus to be 47° 48′ and 44° 57′ when in similar situations to Mercury, mentioned in the note, page 143.; the medium is 46° 22′ 30″, using this angle and the very same calculation as in the note page 143, the distance of Venus from the sun will be found =17288.09 semi-diameters of the earth; hence the distance will be had = 68841174 miles astonishingly near the distance found by Kepler's rule, considering the great difference in the principles of calculation, and a strong proof of the truth of the Copernican system.

‡ Here, (as in the note, page 143,) 23882.84—17275.678585 = 6607.16145 semi-diam. distance of Venus from the earth; hence, inversely 6607.16145: 58″.79: : 23882.84: 16″.26419, and 32′ 2″: 886149: : 16′.26419: 7498 miles, the diameter of Venus. Or, by trigonometry, using the angle 58″.79, and distance 6607.16145, the result is 1.88314; × 3982 = 7498 miles.

§ These are found by dividing the square of the earth's distance from the sun by the square of the distance of Venus from the sun.

The earth's distance from the sun is 95000000 miles, the square of which is 9025000000000000, the distance of Venus from the sun is 68791752 miles, the square of which is 4732305143229504; the former square divided by the latter gives 1.907 for the quotient.

## IV. OF THE EARTH ⊕, *and its* SATELLITE THE MOON☽.

The figure and magnitude of the earth have been already explained in Chapter III. Part I.; and its diurnal and annual revolution round the sun, distance from the sun, seasons of the year, &c. have been shown in Chapter IV.; as it would appear superfluous to repeat those particulars here, this chapter is confined entirely to the moon.

The moon being the nearest celestial body to the earth, and, next to the sun, the most resplendent in appearance, has excited the attention of astronomers in all ages. The Hebrews, the Greeks, the Romans, and, in general, all the ancients, used to assemble at the time of new, or full moon, to discharge the duties of piety and gratitude for its manifold uses. The day being measured by observing the time which the sun took in apparently moving from any meridian to the same again, so the month was measured by the number of days elapsed from new moon to new moon; this month was supposed to be completed in thirty days;† and when the motion of the moon came to be compared with, and adjusted to, the apparent motion of the sun, twelve of these months were thought to correspond exactly with the sun's annual course. The lunar month is of two sorts, periodical and synodical. A periodical month is the time in which the moon finishes her course round the earth, and consists of 27 days 7 hours 43 minutes 5 seconds;* and a synodical month is the time elapsed from new moon to new moon, and consists of 29 days 12 hours 44 minutes 3 seconds. The synodical month was probably the only one observed in the infancy of astronomy.

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* By the process mentioned in the note, page 143., the circumference of the orbit of Venus will be found to be 432231362.123 miles; then, as 224d. 16h. 49m. 10sec.: 432231362.123 miles: : 1 h.: 80149 miles Venus travels per hour.

† The Rev. M. Costard, in his History of Astronomy, supposes that the oldest measure of time (taken from the revolutions of the heavenly bodies) was a month; and, after the length of the year was discovered, the ecliptic, and all other circles, were divided into 360 equal parts, called degrees, because 30 d. × 12 = 360 days, the length of the year.—*Hist. of Astr.* p. 44. In an account of the Pelew Islands, we are told that the inhabitants reckoned their time by months, and not by years; for, when the king entrusted his son to the care of Captain Wilson, he inqured how many *moons* would elapse before he might expect the return of his son. The inhabitants of these islands were totally ignorant of the arts and sciences.

The orbit of the moon is nearly elliptical, having the earth in one of its foci; but the eccentricity of this ellipsis is variable, being the greatest when the line of the apsides is in the syzygies, for then the transverse axis of the moon's orbit is lengthened; and the least when the transverse axis is in the quadratures, for then the conjugate axis is lengthened, and consequently the orbit approaches nearer to a circle. The moon in her revolution round the earth would always describe the same ellipsis, were that revolution undisturbed by the action of the sun; the principal axis of her orbit would remain at rest, and be always of the same quantity; her periodic times would all be equal, and the inclination of her orbit to the ecliptic and the place of her nodes would be invariable; but her motions being disturbed by the action of the sun, they become subject to so many irregularities, that to calculate the moon's place truly, and to establish the elements of her theory, are almost insuperable difficulties.

The orbit of the moon is inclined to the ecliptic in an angle, which is variable from 5° to 5° 18′, consequently it is inclined in an angle of 5° 9′ at a medium. The motion of the moon's nodes, or places where her orbit crosses the orbit of the earth, is westward, or contrary to the order of the signs: this motion is likewise variable, but by comparing together a great number of distant observations, the mean annual retrograde motion is found to be about 19° 19′ 44″, so that the nodes make a complete retrograde revolution from any point of the ecliptic to the same again in about 18 years 228 days 9 hours. The axis of the moon is almost perpendicular to the plane of the ecliptic, the angle being 88° 17′, consequently she has little or no diversity of seasons. The moon turns round her axis, from the sun to the sun again, in 29 days 12 hours 44 minutes 3 seconds, which is exactly the time that she takes to go round her orbit from new moon to new moon, she therefore has constantly the same side turned towards the earth. This, however, is subject to a small variation, called the libration† of the moon, so that she sometimes turns a little more of the one side of her face towards the earth, and sometimes a little more of the other, arising from her uniform motion on her axis and unequal motion in her orbit: this is called her libration in longitude. The moon likewise appears to have a kind of vacillating motion, which presents to our view sometimes more and sometimes less of the spots on her surface towards each pole; this arises from the axis of the moon making an angle of about 1° 43′ with a perpendicular to the plane of the ecliptic; and as this axis maintains its parallelism during the moon's revolution round the earth, it must necessarily change its situation to an observer on the earth; this is called the moon's libration in latitude.

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* Periodical revolution 27.321582 days, synodical 29.530588. *M. Laplace.*

† A lunar globe was published a few years ago by Mr. Russel, which shows not only the libration of the moon in the most perfect manner, but is a complete picture of the mountains, pits, and shades, on her surface.

While the moon revolves round the earth in an elliptical orbit, she likewise accompanies the earth in its elliptical orbit round the sun; by this compound motion her path is every where concave towards the sun.*

The moon, like the planets, is an opaque body, and shines entirely by the light received from the sun, a portion of which is reflected to the earth. As the sun can only enlighten one-half of a spherical surface at once, it follows that according to the situation of an observer, with respect to the illuminated part of the moon, he will see more or less of the light reflected from her surface. At the conjunction, or time of new moon, the moon is between the earth and the sun, and consequently that side of the moon which is never seen from the earth is enlightened by the sun; and that side which is constantly turned towards the earth is wholly in darkness.† Now, as the mean motion of the moon in her orbit exceeds the apparent motion of the sun by about 12° 11′ in a day,‡ it follows that, about four days after the new moon, she will be seen in the evening a little to the east of the sun, after he has descended below the western part of the horizon. A spectator will see the convex part of the moon towards the west, and the horns or cusps towards the east: or if the observer live in north latitude, as he looks at the moon the horns will appear to the left hand; for if the line joining the cusps of the moon be bisected by a perpendicular passing through the enlightened part of the moon, that perpendicular will point directly to the sun. As the moon continues her motion eastward, a greater portion of her surface towards the earth becomes enlightened; and when she is 90 degrees eastward of the sun, which will happen about 7⅓ days from the time of new moon, she will come to the meridian about six o'clock in the evening, having the appearance of a bright semi-circle; advancing still to the eastward, she becomes more enlightened towards the earth, and at the end of about 14¾ days, she will come the meridian at midnight, being diametrically opposite to the sun; and consequently she appears a complete circle, or it is said to be *full moon.* The earth is now between the sun and the moon, and that half of her surface which is constantly turned towards the earth is wholly illuminated by the direct rays of the sun; whilst that half of her surface, which is never seen from the earth is involved in darkness. The moon continuing her progress eastward, she becomes deficient on her western edge, and about 7⅓ days from the full moon she is again within 90 degrees of the sun, and appears a semi-circle with the convex side turned towards the sun: moving on still eastward, the deficiency on her western edge becomes greater, and she appears a crescent, with the convex side turned towards the east, and her cusps or horns turned towards the west: and about 14½ days from the full moon she has again overtaken the sun, this period being performed in 29 days 12 hours 44 minutes 3 seconds, as has been observed before. Hence, from the new moon to the full moon, the phases are *horned*, *half-moon*, and *gibbous;* and as the convex or well-defined side of the moon is always turned towards the sun, the horns or irregular side will appear to the east, or towards the left hand of a spectator in north latitude. From the full moon to the change, the phases are *gibbous*, *half-moon*, and *horned;* the convex or well-defined side of her face will appear to the east, and her horns or irregular side towards the west, or to the right hand of a spectator.

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* See M. Maclaurin's account of Sir Isaac Newton's discoveries, book iv. chap. 5; Rowe's Fluxions, second edition, page 225.; Ferguson's Astronomy, octavo edition, article 226.; or, a Treatise on Astronomy, by Dr. Olinthus Gregory, article 458.

† Except the light which is reflected upon it from the earth, which we cannot perceive.

‡ See the note, page 91.

As the full moons always happen when the moon is directly opposite to the sun, all the full moons, in our winter, happen when the moon is on the north side of the equinoctial. The moon, while she passes from Aries to Libra, will be visible at the north pole, and invisible during her progress from Libra to Aries; consequently, at the north pole, there is a fortnight's moonlight and a fortnight's darkness by turns. The same phenomena will happen at the south pole during the sun's absence in our summer. If the earth, the moon, and the sun were all in the same plane, there would be an eclipse of the sun at every new moon, (for then the moon is between the earth and the sun,) and there would be an eclipse of the moon at every full moon, at which time the earth is between the sun and the moon. But as the orbit of the moon crosses the orbit of the earth or the ecliptic in two opposite points called the nodes, it is evident that the moon is never in the ecliptic except when she is in one of these nodes; an eclipse, therefore, can never happen unless the moon be in or near one of these nodes; at all other times she is either above or below the orbit of the earth; and though the moon crosses each of these nodes every month, yet if there should not be a new or full moon, at or near that time, there will be no eclipse. (*See more of this subject in a succeeding chapter.*) The influence of the moon upon the waters of the ocean has already been explained; and the nature of the harvest-moon will be shown amongst the problems on the globes.

The moon's greatest horizontal parallax is 61′ 32″, the least 54′ 4″, consequently the mean horizontal parallax is 57′ 48″*; and her mean distance from the earth 236847 miles.† The apparent diameter of the moon is variable according to her distance from the earth; her mean apparent diameter is stated to be 31′ 7″‡; hence her real diameter is 2144 miles§, and her magnitude about $\frac{1}{50}$ of the magnitude of the earth. The moon performs her revolutions round the earth in 27 days 7 hours 43 minuts 5 seconds, and has been observed before, consequently she travels at the

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* Dr. Hutton's Mathematical Dict. word Parallax.

† As in the note, page 80.

| | |
|---|---|
| Sine of angle PSO 57′ 48″ - - - - | 8.2256335 |
| Is to semi-diameter of the earth PO - | 0.0000000 |
| As to radius, sine of 90 =sine OPS - | 10.0000000 |
| Is to 59.47938 semi-diameters, - - | 1.7743665 |

Hence 59.47938 × 3882=236846.89 miles, distance of the moon from the earth.

‡ *Vince's* Astronomy. *Woodhouse's* Astronomy, page 314.

§ As in the preceding notes say, inversely, 59.47938 semi-diam. : 31′ 7″ :: 23382.84 sem. : 4″.6497, the apparent diameter of the moon at a distance from the earth equal to that of the sun; hence 32′ 2″ : 886149 : 4″.6497 : 2143.8 miles the diameter of the moon. Or, by trigonometry, the angle *m o n*, (*Plate* IV. *Fig.* 3.)=31′ 7″, hence

$$o\,m\,n = \frac{180° - 31'\,7''}{2} = 89°\;59'\;44''\;26\tfrac{1}{2}'''.$$

| | |
|---|---|
| Sine of 89° 59′ 44″, &c. = (sine of 90 nearly - - - - | 10.0000000 |
| Is to 59.47938 semi-diameters - - - - - - - - - - | 1.7743665 |
| As sine 31′ 7″ - - - - - - - - - - - - - - - | 7.9567310 |
| Is to .53839 semi-diameters of the earth - - - - - - - | 1.7310975 |

And to .53839 × 3982=2143.86, &c. miles the diameter of the moon: See the notes, page 143. If the cube of the earth's diameter be divided by the cube of the moon's diameter, the quotient will be 51.2; hence the magnitude of the earth is rate of 2270[*] miles per hour round the earth, besides attending the earth in its annual journey round the sun.

The surface of the moon is greatly diversified with inequalities, which through a telescope have the appearance of hills and vallies. Astronomers have drawn the face of the moon as viewed through a telescope, distinguishing the dark and shining parts by their proper shades and figures. Each of the spots on the moon has been marked by a numerical figure, serving as a reference to the proper name of the particlar spot which it represents; as, * Herschel's volcano; 1, Grimaldi; 2, Galileo, &c.; so that the several spots are named from the most noted astronomers, philosophers, and mathematicians. The best and most complete picture of the moon is that drawn on Mr. Russel's lunar globe.

Dr. Herschel informs us that, on the 19th of April, 1787, he discovered three volcanoes in the dark part of the moon; two of them appeared nearly extinct, the third exhibited an actual eruption of fire, or luminous matter. On the subsequent night it appeared to burn with greater violence, and might be computed to be about three miles in diameter. The eruption resembled a piece of burning charcoal, covered with a thin coat of white ashes; all the adjacent parts of the volcanic mountain were faintly illuminated by the eruption, and were gradually more obscure at a greater distance from the crater. That the surface of the moon is indented with mountains and caverns, is evident from the irregularity of that part of her surface which is turned from the sun: for, if there were no parts of the moon higher than the rest, the light and dark spots of her disc at the time of the quadratures would be terminated by a perfectly straight line; and at all other times the termination would be an elliptical line, convex towards the enlightened part of the moon in the first and fourth quarters, and concave in the second and third: but instead of these lines being regular and well defined when the moon is viewed through a telescope, they appear notched and broken in innumerable places. It is rather singular that the edge of the moon, which is always turned towards the sun, is regular and well defined, and at the time of full moon no notches or indented parts are seen on her surface. In all situations of the moon, the elevated parts are constantly found to cast a triangular shadow with its vertex turned

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[*] For, by the note, page 143, 113 : 355 : : 236346.9 × 2 : 1488153.09 miles circumference of the moon's orbit; then 27 d. 7 h. 43 m. 5 sec. : 1488153.09 m. : : 1 h. : 2269.5 miles.

[illegible] and, on the contrary, the cavities are always dark on the side next the sun, and illuminated on the opposite side; these appearances are exactly conformable to what we observe in [illegible] valleys on the earth: and even in the dark part of the moon's disc, near the borders of the lucid surface, some minute specks have been seen, apparently enlightened by the sun's rays: these shining spots are supposed to be the summits of high mountains*; which are illuminated by the sun, while the adjacent valleys nearer the enlightened part of the moon are entirely dark.

Whether the moon has an atmosphere or not, is a question that has long been controverted by various astronomers: some endeavour to prove, that the moon has neither an atmosphere, seas, nor lakes; while others contend that she has all these in common with our earth, though her atmosphere is not so dense as ours. It cannot be expected in an introductory treatise, where general received truths only ought to be admitted, that we should enter into the discussion of a controverted question; however, it may be proper to inform the student, that the advocates for an atmosphere, if we may be allowed to reason from analogy, have the advantage over those who contend that there is none. It is admitted on all hands, that the moon has mountains and valleys, like the earth, and appears nearly the same with respect to shape and the nature of her motions. May we not then fairly infer that she is similar to the earth in other respects?

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* Supposing this to be the fact, astronomers have determined the height of some of the lunar mountains. The method made use of by Riccioli (though it gives the true result only at the time of the qadratures) is here explained, because it is much more simple than the general method given by Dr. Herschel in the Philosophical Transactions for 1780. Let ADB (*Plate* IV. *Fig*. 7.) be the disc or face of the moon at the time of the quadratures, ACB the boundary of light and darkness; MO a mountain in the dark part, the summit M of which is just beginning to be enlightened, by a ray of light SAM from the sun. Now, by means of a micrometer, the ratio of MA to AB may be determined; and as AC is the half of AB, and MAC a right angled triangle by Euclid 1 and 47th $\sqrt{AC^2+AM^2}=CM$, from which take $CO=AC$, and the remainder MO, is the height of the mountain. Riccioli observed the illuminated part of the mountain St. Catherine, on the fourth day after the new moon, to be distant from the illuminated part of the moon about 1-sixteenth part of the moon's diameter, viz. MA = 1-sixteenth of AB, or = 1-eighth of AC; now, if we take the moon's diameter 2144 miles, as we have before determined, the height of this mountain will be $8\frac{3}{16}$ miles! Galileo makes MA = 1-20th of AB; and Hevelius makes MA = 1-26th of AB; the former of these will give the height of the mountain $5\frac{3}{16}$ miles, and the latter $3\frac{1}{16}$ miles. Dr. Herschel thinks, "that the hights of the lunar mountains are in general greatly over-rated, and that the generality of them do not exceed half a mile in their perpendicular elevation." On the contrary, M. Schroeter, a learned astronomer of Lilienthal, in the duchy of Bremen, says, that there are mountains in the moon much higher than any on the earth, and mentions one above a thousand toises higher than Chimboraco in South America. The same author has lately published a new work on the heights of the mountains of Venus, some of which he makes upwards of twenty-three thousand toises in height, which is above seven times the height of Chimboraco!

Mars

## V. OF MARS ♂.

Mars appears of a dusky red colour, and though he is sometimes apparently as large as Venus, he never shines with so brilliant a light. From the dulness and ruddy appearance of this planet, it is conjectured that he is encompassed with a thick cloudy atmosphere, through which the red rays of light penetrate more easily than the other rays. This being the first planet without the orbit of the earth, he exhibits to the spectator different appearances to Mercury and Venus. He is sometimes in conjunction with the sun, like Mercury and Venus, but was never known to transit the sun's disc. Sometimes he is directly opposite to the sun, that is, he comes to the meredian at midnight, or rises when the sun sets, and sets when the sun rises; at this time he shines with the greatest lustre, being nearest to the earth. Mars, when viewed through a telescope, appears sometimes full and round, at others gibbous, but never horned. The foregoing appearances clearly show, that Mars moves in an orbit more distant from the sun than that of the earth. The apparent motion of this planet, like that of Mercury and Venus, is sometimes direct, or from east to west; at others retrograde, or from west to east; and sometimes he appears stationary. Sometimes he rises before the sun, and is seen in the morning; at others he sets after the sun, and of course is seen in the evening. Mars revolves on its axis in 24 hours 39 minutes 22 seconds; and its polar diameter is to its equatorial diameter as 15 to 16, according to Dr. Herschel; but Dr. Maskelyne, who carefully observed this planet at the time of opposition, could perceive no difference between its axes. The inclination of the orbit of Mars to the plane of the ecliptic is 1° 51′; the place of his ascending node about 18° in Taurus,* his horizontal parallax is said to be 23″.6; he performs his revolution round the sun in 1 year 321 days 23 hours 15 minutes 44 seconds; and his apparent semi-diameter, at his nearest distance from the earth, is 25″; consequently his mean distance from the sun is 144907630* miles; his diameter 4218 miles; and his magnitude a little more than $\frac{1}{7}$th of that of the earth.† This planet travels round the sun at the rate of 55223 miles per hour‡; and the parallax of the earth's annual orbit, as seen from Mars, is about 41 degrees. As the distances of the interior planets from the sun are found by their elongations, so the distances of the exterior planets may be found by the parallax of the earth's annual orbit.§

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* The longitude of the ascending node of Mars for the beginning of the year 1750 was 17° 38′ 38″ in Taurus, and its variation in 100 years is 46′ 40″.—*Vince's Astronomy.*

## VI. Of Vesta ⚶.

This planet was discovered by *Dr. Olbers*, of Bremen, on the

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* For, 686 days 23 hours 15 min. 44 sec.=59354144 seconds, the square of which is 3522914409972736, this divided by 995839704797184 the seconds in a year (see the note, page 142), gives 3.537632, the cube-root of which is 1.523716, the *relative* distance of Mars from the sun. Hence 1.5237186 × 23882.84=36390.6654 distance of Mars from the sun in semi-diameters of the earth, and 36390.6654 × 3982=144907629.6 miles, the mean distance of Mars from the sun. Now, if the horizontal parallax of Mars at the time of opposition be 23″.6, as stated by M. de la Caille, we have (*see Plate* IV. *Fig.* 6.)

Sine PSO=sine 23″.6 . . . . . . . . . . . 6.0583927
Is to PO=1 semi-diameter . . . . . . . . 0.0000000
As radius sine of 90° . . . . . . . . . . .10.0000000
Is to SG=8741.93 semi-diameter . . . . 3.9416073

Hence the distance of Mars from the earth at the time of opposition is 8741.93 of the earth's semi-diameters; 8741.93 : 25″ : : 23882.84 : 9″.15 the apparent diameter of Mars if seen from the earth at a distance equal to that of the sun; then 32′.2″ : 886149 : : 9″.15 : 4218 miles the diameter of Mars.

† The cube of 7964, the diameter of the earth, is 505119057344; and the cube of 4218, the diameter of Mars, is 75044648232; the quotient produced by dividing the former by the latter, is 6.73. viz. the magnitude of the earth is nearly seven times that of Mars.

‡ For, 113 : 355 : : 144907630 × 2 : 910481569 miles the circumference of the orbit of Mars, and 686 days 23 h. 15 min. 44 sec. : 910481569 m. : : 1 h. : 55223 miles.

§ *In Plate* IV. *Fig.* 8. let S represent the sun, E the earth, and M Mars; now, as the earth moves quicker in its orbit than Mars, the planet Mars will appear to go backward when the earth passes it. Thus, when the earth is at E, Mars will appear among the fixed stars at *m*; but as the earth passes from E to *e*, Mars will appear to go from *m* to *n*, though he is in reality travelling the same way as the earth from M to O. The place *m*, where Mars is seen from the earth among the fixed stars, is called his GEOCENTRIC place, but the place P, where he would be seen from the sun, is called his HELIOCENTRIC place, and the arc *m* P, which is the difference between his apparent and true place, is called the PARALLAX OF THE EARTH'S ANNUAL ORBIT. Now, as this angle may be determined from observation, and is known to be about 41°; in the right-angled triangle SEM, we have have given SE=23882.84 semi-diameters, the distance of the earth from the sun, the angle SMB measured by the arc *m* P=41°, to find SM=36403.49 semi-diameters of the earth, the distance of Mars from the sun. According to *M. Laplace*, the sidereal revolution of Mars is performed in 686.979619 days, and his mean distance

29th of March 1807; its distance from the sun is 225435000* miles, and the length of its year, 3 years 240 days 5 hours. Vesta appears like a star, of the fifth magnitude.

### VII. OF JUNO ⚵.

Juno was discovered by *Mr. Harding*, of Lilienthal, in the duchy of Bremen, on the first of September, 1804. It appears like a star of the eighth magnitude; its distance from the sun is 253380485 miles, and its periodical revolution is performed in 4 years and 131 days.

### VIII. OF CERES ⚳.

Ceres was discovered by *M. Piazzi*, astronomer royal, at Palermo, in the island of Sicily, on the first of January, 1801. The length of its year is four years 221 days 13 hours; its distance from the sun is 262903570 miles, and its diameter, according to Dr. Herschel, is about 172 miles. Ceres appears like a star of the eighth magnitude.

### IX. OF PALLAS ⚴.

Pallas was discovered by *Dr. Olbers*, on the 28th of March, 1802. The length of its year is 4 years 221 days 17 hours; and its distance from the sun 262921240 miles. Pallas appears like a star of the seventh magnitude, and its diameter is stated to be about 110 miles.

### X. OF JUPITER ♃, *and his Satellites.*

Jupiter is the largest of all the planets, and notwithstanding his great distance from the sun and the earth, he appears to the naked eye almost as large as Venus, though his light is something less brilliant. Jupiter, when in opposition to the sun, (that is, when he comes to the meridian at midnight, or rises when the sun sets, and sets when the sun rises,) is much nearer to the earth than he is a little before and after his conjunction with the sun;

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* Mean distance 2.373. The mean distance of *Juno* is 2.667173, of *Ceres* 2.767406, of *Pallas* 2.767592 according to *Laplace*, and the periods which are given from the same author, are sidereal periods.

hence, at the time of opposition, he appears larger and more luminous than at other times. When the longitude of Jupiter is less than that of the sun, he will be a morning star, and appear in the east before the sun rises; but, when his longitude is greater than the sun's longitude, he will be an evening star, and appear in the west after the sun sets. Jupiter revolves on his axis in 9 hours 56 minutes, which is the length of his day; but as his axis is nearly perpendicular to the plane of his orbit, he has no diversity of seasons. Jupiter is surrounded by faint substances called zones or belts; which, from their frequent change in number and situation, are generally supposed to consist of clouds. One or more dark spots frequently appear between the belts; and when a belt disappears, the contiguous spots disappear likewise. The time of the rotation of the different spots is variable, being less by six minutes near the equator than near the poles. Dr. Herschel has determined, that not only the times of rotation of the different spots vary, but that the time of rotation of the same spot (between the 25th of February 1773 and the 12th of April) varied from 9 hours 55 minutes 20 seconds, to 9 hours 51 minutes 35 seconds.

The inclination of the orbit of Jupiter to the plane of the ecliptic is 1° 18 56″; the place of his ascending node about 8 degrees in Cancer[*]; and he performs his revolution round the sun in 11 years 315 days 14 h. 27 m. 11 sec. moving at the rate of 29894 miles per hour, his mean distance from the sun being 494499108 miles.[†] Jupiter, at his mean distance from the earth, at the time of opposition, subtends an angle of 46″, hence his real diameter is 89069 miles[‡] and his magnitude 1400 times that of the earth.[§]

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[*] The place of Jupiter's ascending node for the beginning of the year 1750 was 7° 55′ 32″ in Cancer, and its variation in 100 years is 59′ 30″. *Vince's Astronomy.*

[†] For, 4330 days 14 h. 27 min. 11 sec.=374164031 seconds, the square of which is 139998722094168961; this divided by 995839704797184, the square of the seconds in a year, (see the note, page 142,) gives 140.5835913, the cube root of which is 5.1997, the relative distance of Jupiter from the sun. Hence 23882.84 × 5.1997 =124183.603148 distance of Jupiter from the sun in semi-diameters of the earth; and 124183.603148 × 3982=494499107 7 miles, the mean distance of Jupiter from the sun. According to *Laplace* the sidereal period of Jupiter is 4332.596308 days, and his mean distance from the sun 5.202791.

Now, (by the note, page 143,) 113 : 355 : : 494499107.7 × 2 : 3107029791 miles, the circumference of the orbit of Jubiter, and 4330 d. 14 h. 27 min. 11 seconds, : 3107029791 : : 1 h. : 29894 miles

[‡] 494499108—95101468 miles the distance of the earth from the sun, = 399397640 distance of the earth from Jupiter. Now, by the rule of three inversely, 399397640 : 46″ : : 95101468 : 193″.1862, the apparent diameter of Jupiter at a distance from the earth equal to that of the sun. Hence, (as in the note, page 143,) 32′ 2″ : 886149 : : 193″.1862 : 89069.5 miles, the diameter of Jupiter.

[§] For, if the cube of the diameter of Jupiter be divided by the cube of the diameter of the earth, the quotient will be 1398,9 = 1400 nearly.

The light and heat which Jupiter receives from the sun is about $\frac{1}{27}$ of the light and heat which the earth receives.*

On account of the great magnitude of Jupiter, and his quick revolution on his axis, he is considerably more flatted at the poles than the earth is. The ratio between his polar and equatorial diameters, has been differently stated by different astronomers: Dr. Pound makes it as 12 to 13; Mr. Short, as 13 to 14; Dr. Bradley, as $12\frac{1}{2}$ to $13\frac{1}{2}$; and Sir Isaac Newton (by theory) $9\frac{1}{3}$ to $10\frac{1}{3}$.

## *Of the Satellites of Jupiter.*

Jupiter is attended by four satellites or moons, each of which revolves round him in a manner similar to that of the moon round the earth. The times of their periodical revolutions round Jupiter, and their respective distances, from his centre, are given in the following table :†

| Satellites. | Periodical revolution. | Distance from Jupiter in semi-diameters. | Distance from Jupiter in English miles. |
|---|---|---|---|
| | d. h. m. sec. | | |
| I. | 1 . 18 . 27 . 33 | 5.67 | 252510 |
| II. | 3 . 13 . 13 . 42 | 9.00 | 400810 |
| III. | 7 . 3 . 42 . 33 | 14.38 | 640406 |
| IV. | 16 . 16 . 32 . 8 | 25.30 | 1126723 |

The satellites of Jupiter are invisible to the naked eye; they were first discovered by Galileo, the inventor of telescopes, in the year 1610. This was an important discovery; for, as these satellites revolve round Jupiter in the same direction which Jupiter revolves round the sun, they are frequently eclipsed by his shadow, and afford an excellent method of finding the true lon-

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* If the square of the mean distance of Jupiter from the sun be divided by the square of the mean distance of the earth from the sun, the quotient will be 27.

† The second and third columns in the above table are copied from *M. de la Lande*, and the fourth is found by multiplying the numbers in the third column by 44534.5, being the half of 89069, the diameter of Jupiter. The distances of the satellites from the centre of Jupiter may be found at the time of their greatest elongations, by measuring their distances from the centre of Jupiter, and also the diameter of Jupiter with a micrometer. Then say, as the apparent diameter of Jupiter (by the micrometer) is to his real diameter, so is the apparent distance of the satellite to its real distance. Or, having determined the periodical times of the satellites, and the distance of one of them from the sun, the distances of all the rest may be found by Kepler's rule, as in page 142.

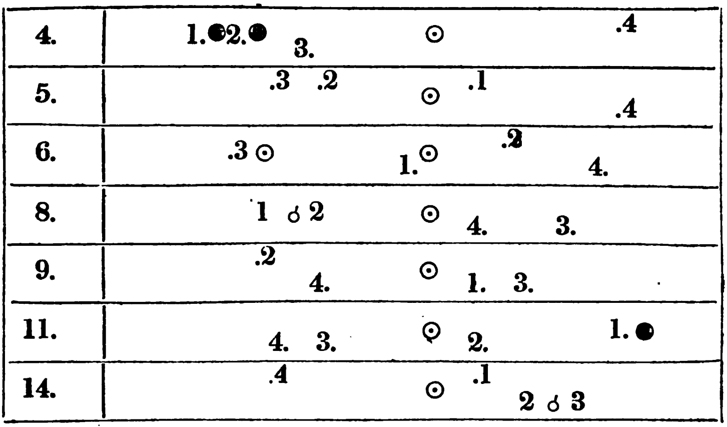
longitudes of places on the land. To these eclipses we likewise owe the discovery of the progressive motion of light, and hence the aberration of the fixed stars.

The satellites of Jupiter do not revolve round him in the same plane, neither are their nodes in the same place. These satellites appear of different magnitudes and brightness, the fourth *generally* appears the smallest, but sometimes the largest, and the apparent diameter of its shadow on Jupiter is sometimes greater than the satellite. M. Cassini and Mr. Pound supposed that the satellites of Jupiter revolved on their axes; and Dr. Herschel has discovered that they revolve about their axes in the time in which they respectively revolve about Jupiter.

The first satellite is the most important of the four, from its numerous eclipses. The times of the eclipses of the satellites of Jupiter are calculated for the meridian of Greenwich, and inserted in the IIId page of the Nautical Almanac for every month, and their configurations or appearances, with respect to Jupiter, are inserted in page XII. As the earth turns on its axis from west to east at the rate of 15 degrees in an hour, or one degree in four minutes of time, a person one degree westward of Greenwich, will observe the immersion or emersion of any one of the satellites of Jupiter four minutes later than the time mentioned in the Nautical Almanac; and, if he be one degree eastward of Greenwich, the eclipse will happen four minutes sooner at his place of observation than at Greenwich. These eclipses must be observed with a good telescope and a pendulum clock which beats seconds or half-seconds.

The configurations of the satellites of Jupiter at eight o'clock at night in the month of March, and in the year 1825, are given in the XIIth page of the Nautical Almanac as in the following page: an explanation of which will render the XIIth page of that work intelligible to a young student for any other year and month.

Jupiter is distinguished by the mark ○, and the satellites by points with figures annexed: the figure 1 signifying the first satellite, 2 the second, &c. When the satellite is approaching Jupiter, the figure is placed between Jupiter and the point; and when the satellite is receding from Jupiter, the point is placed between the figure and Jupiter.



On the *fourth* day of the month, given above, the first and second satellites are eclipsed at eight at night; the third is on the left hand of Jupiter, and receding from the planet, and the fourth is on the right hand receding.

On the *fifth* day of the month, at the same hour, the third and second satellites are on the left hand of Jupiter, and are approaching him; the first is on the right hand receding from the planet, and the fourth is on the right hand approaching it.

On the *sixth* day the third satellite will appear like a bright spot on the disc of Jupiter; the first will be on the left hand receding from Jupiter; the second and fourth on the right hand, the second receding from, and the fourth approaching the planet.

On the *eigth* day the first and second satellites are in conjunction on the left hand of Jupiter; the fourth and third are on the right hand approaching the planet.

On the *fourteenth* day the fourth satellite is on the left hand approaching Jupiter, the first on the right hand receding from Jupiter, and the second and third in conjunction on the right hand.

By observations on the satellites of Jupiter the progressive motion of light was discovered; for it has been found by repeated experiments; that, when the earth is exactly between Jupiter and the sun, the eclipses of Jupiter's satellites are seen 8¼ minutes later than the time predicted; hence it is inferred that light takes up about 16½ minutes of time to pass over a space equal to the diameter of the earth's annual orbit, which is 190 millions of miles, or double of the distance of the earth from the sun; for if the effects of light were instantaneous, the eclipses of the satellites would in all situations of the earth in its orbit happen exactly at the time predicted by calculation.

### OF SATURN ♄ *his Satellites and Ring.*

Saturn shines with a pale, feeble light, being the farthest from the sun of any of the planets that are visible without a telescope. This planet, when viewed through a good telescope, always engages the attention of the young astronomer by the singularity of its appearance. It is surrounded by an interior and exterior ring, beyond which are seven satellites or moons, all, except one, in the same plane with the rings. These rings and satellites are all opaque and dense bodies, like that of Saturn, and shine only by the light which they receive from the sun. The disc of Saturn is likewise crossed by obscure zones or belts, like those of Jupiter, which vary in their figure according to the direction of the rings. Saturn performs his revolution round the sun in 29 years 174 days 1 hour 51 minutes 11 seconds*; hence his mean distance from the sun is 907089032 miles†; and his progressive motion in his orbit is 22072 miles per hour.

The inclination of the orbit of Saturn to the plane of the ecliptic is said to be 2° 29′ 50″, and the place of his ascending node about 21 degrees in Cancer.‡

Saturn, at his mean distance from the earth, subtends an angle of 20″; hence his real diameter is 78730* miles and his magnitude 966† times that of the earth. The light and heat which this planet receives from the sun is about $\frac{1}{100}$ part‡ of the light and heat which the earth receives.

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* *Laplace* states the sidereal period of Saturn to be 10758.96984 days, and his mean distance from the sun 9.53877; see also *Abrégès d' Astronomie, par M. Delambre*, page 452. Paris, 1813.

† For 10759 d. 1 h. 51 min. 11 sec.=929584271 seconds, the square of which is 864126916890601441, this divided by 995839704797184, the square of the seconds in a year (see the note, page142.) gives 867.736958, the cube root of which is 9.538118, the relative distance of Saturn from the sun. Hence 23882.84 × 9.53118 =227797.34609512 distance of Saturn from the sun in semi-diameters of the earth; and 227797.34609512 × 3982=907089032.15 miles, the mean distance of Saturn from the sun. 113 : 355 : 907089032 × 2 : 5699408962.1238 miles circumference of the orbit of Saturn. Then, 10759 d. 1h. 51m. 11 sec. : 5699408962 miles : : 1 h. : 22072 miles which Saturn moves per hour in his orbit.

‡ The place of Saturn's ascending node for the beginning of the year 1750 was 21° 32′ 22″ in Cancer, and its variation in 100 years is 55′ 30″. *Vince's Astronomy.*

According to Dr. Herschel, Saturn revolves on his axis from west to east in 10 hours 16 min. 2 sec. and this axis is perpendicular to the plane of his ring. The equatorial diameter of Saturn, viz. the diameter in the direction of the ring, is to the polar diameter, viz. the axis, as 11 to 10.

## *Of the Satellites of Saturn.*

Saturn is attended by seven moons; the *fourth* was discovered be Huygens, a Dutch mathematician, in the year 1655. The *first*, *second*, *third*, and *fifth*, were discovered at different times, between the years 1671 and 1685, by Cassini, a celebrated Italian astronomer. The *sixth* and *seventh* satellites were discovered by Dr. Herschel in the years 1787 and 1789. The two satellites discovered by Dr. Herschel are nearer to Saturn than the other five, and therefore should be called the *first* and *second;* but to distinguish them from the other satellites, and to prevent confusion in referring to former observations, they are called the sixth and seventh satellites. The seventh satellite, which is nearest to Saturn, was discovered a short time after the sixth. In the following table, the satellites are arranged according to their respective distances from Saturn, and the Roman figures in the left-hand column show the number of the satellite. The figures between the parentheses show the order in which they ought to be numbered.

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* 907089032—95101468 miles, the distance of the earth from the sun, = 811987564 miles distance of the earth from Jupiter. Now, inversely, 811987564 : 20″ : : 95101468 : 170″.762, the apparent diameter of Saturn at a distance from the earth equal to that of the sun (by the note, page 143); 32′ 2″ : 886149 : : 170″.762 : 78730 miles, the diameter of Saturn.

† Found by dividing the cube of the diameter of Saturn by the cube of the diameter of the earth.

‡ Found by dividing the square of the mean distance of Saturn from the sun by the square of the earth's mean distance from the sun.

| Satellites. | | Periodical revolution. | Distance from Saturn in semi-diameters from *Laplace*. | Distance from Saturn in English miles. |
|---|---|---|---|---|
| | | d. h. m. sec. | | |
| VII. | (1) | 0 . 22 . 37 . 23 | 3.080 | 121244 |
| VI. | (2) | 1 . 8 . 53 . 9 | 3.952 | 155570 |
| I. | (3) | 1 . 21 . 18 . 27 | 4.893 | 192613 |
| II. | (4) | 2 . 17 . 44 . 51 | 6.268 | 246740 |
| III. | (5) | 4 . 12 . 25 . 11 | 8.754 | 344601 |
| IV. | (6) | 15 . 22 . 41 . 16 | 20.295 | 798912 |
| V. | (7) | 79 . 7 . 53 . 43 | 59.154 | 2328597 |

The first, second, third, and fourth satellites, as well as the sixth and seventh, are all nearly in the same plane with Saturn's ring, and are inclined to the orbit of Saturn in an angle of about 30 degrees; but the orbit of the fifth satellite is said to make an angle of fifteen degrees with the plane of Saturn's ring. Sir Isaac Newton conjectured* that the fifth satellite of Saturn revolved round its axis in the same time that it revolved round Saturn; and the truth of his opinion has been verified by the observations of Dr. Herschel.

## *Of Saturn's Ring.*

The ring of Saturn is a thin, broad, and opaque circular arch, surrounding the body of the planet without touching it, like the wooden horizon of an artificial globe. If the equator of the artificial globe be made to coincide with the horizon, and the globe be turned on its axis from west to east, its motion will represent that of Saturn on its axis, and the wooden horizon will represent the ring, especially if it be supposed a little more distant from the globe. The ring of Saturn was first discovered by Huygens; and when viewed through a good telescope, appears double. Dr. Herschel says, that Saturn is encompassed by two concentric rings, of the following demensions:

| | Miles. |
|---|---|
| Inner diameter of the smaller ring - - | 146345 |
| Outside diameter of ditto - - - | 184393 |
| Inner diameter of the larger ring - - | 190248 |

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[*] Principia, Book III. Prop. xvii.

| | |
|---|---|
| Outside diameter of ditto - - - - | 204883 |
| Breadth of the inner ring - - - - | 20000 |
| Breadth of the outer ring - - - - | 7200 |
| Breadth of the vacant space, or dark zone between the rings - - - - - - | 2839 |

The ring of Saturn revolves round his axis and in a plane coincident with the plane of his equator, in 10 hours 32 min. 15.4 sec. The ring being a circle, appears elliptical, from its oblique position; and it appears most open when Saturn's longitude is about 2 signs 17 degrees, or 8 signs 17 degrees. There have been various conjectures relative to the nature and properties of this ring.

## XII. OF THE GEORGIUM SIDUS, OR HERSCHEL ♅, *and its Satellites.*

The *Georgian* is the remotest of all the known planets belonging to the solar system; it was discovered at Bath by Dr. Herschel on the 13th of March, 1781. This planet is called by the English the *Georgium Sidus*, or *Georgian*, a name by which it is distinguished in the Nautical Almanac. It is frequently called by foreigners *Herschel*, in honour of the discoverer. The royal academy of Prussia, and some others, called it *Ouranus*, because the other planets are named from such heathen deities as were relatives: thus *Ouranus* was the father of Saturn, *Saturn* the father of Jupiter, *Jupiter* the father of Mars, &c. This planet, when viewed through a telescope of a small magnifying power, appears like a star of between the 6th and 7th magnitudes. In a very fine clear night, in the absence of the moon, it may be perceived, by a good eye, without a telescope. Though the Georgium Sidus was not known to be a planet till the time of Dr. Herschel, yet astronomers generally believe that it has been seen long before his time, and considered as a fixed star.*

In so recent a discovery of a planet at such an immense distance, the theory of its magnitude, motion, &c. must be in some degree imperfect. Its periodical revolution round the sun is said to be performed in 83 years 150 days 18 hours:* the ratio of its diameter to that of the earth, is as 4.32 to 1; consequently its magnitude is upwards of eighty times that of the earth.

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* According to F. de Zach's account of this planet in the Memoirs of the Brussels Academy, 1785, there was then in the library of the Prince of Orange, four observations of this planet considered as a star, in a catalogue of observations written by Tycho Brahe; but, as Tycho was not acquainted with the use of telescopes, some writers contend that he could not see it; while others maintain that, as he has marked stars which are not greater than this planet, he might certainly have seen it. This planet was likewise seen by Professor Mayer of Gottingen, in the year 1756, being the 964th of his catalogue.

The Georgian planet is attended by six satellites; their periodical revolutions and times of discovery are as follow:

| | d. | h. | m. | s. | |
|---|---|---|---|---|---|
| I. or nearest, revolves in | 5 | 21 | 25 | 0, | discovered in 1798 |
| II. - - | 8 | 17 | 1 | 19, | discovered in 1787 |
| III. - - | 10 | 23 | 4 | 0, | discovered in 1798 |
| IV. - - | 13 | 11 | 5 | 1½, | discovered in 1787 |
| V. - - | 38 | 1 | 49 | 0, | discovered in 1798 |
| VI. - - | 107 | 16 | 40 | 0, | discovered in 1798 |

All these satellites were discovered by Dr. Herschel; their orbits are said to be nearly perpendicular to the ecliptic, and what is more singular, they perform their revolutions round the Georgian planet in a retrograde order, viz. contrary to the order of the signs.

## CHAPTER VI.

*On the Nature of Comets; the Elongations, Stationary, and Retrograde Appearance of the Planets; and on the Eclipses of the Sun and Moon.*

### ON COMETS.

Though the primary planets already described, and their satellites, are considered as the whole of the regular bodies which form the solar system, yet that system is sometimes visited by other bodies, called *comets*, which are *supposed* to move round the sun in elliptical orbits. These orbits are supposed to have the sun in one of the foci, like the planets; and to be so very eccentric, that the comet becomes invisible when in that part of its orbit which is the farthest from the sun. It is extremely difficult to determine the elliptic orbit of a comet, with any degree of accuracy by calculation; for, if the orbit be very eccentric, a small error in the observation will change the computed orbit into a parabola or hyperbola; and from the thickness and inequality of the atmosphere with which a comet is surrounded, telescopic observations on them are always liable to error. Hence the theory of the orbits, motions, &c. of comets, is very imperfect; and though many volumes have been written on the subject*, they are chiefly founded on conjecture. The unexpected appearance of the comet in 1807 fully confirms this assertion, and will doubtless give rise to a variety of new calculations, and new hypotheses, which, like former ones, for want of sufficient data, will disappoint the expectations of succeeding astronomers. The same observations will apply to the very brilliant comet which appeared in the months of September, October, and November, 1811. Among all the different comets that have appeared, the period of only *one* of them is known with any degree of accuracy, viz. that which was observed in 1531, 1607, and 1682, being about 76 years. The comets, Sir Isaac Newton† observes, are compact, solid, and durable bodies, or a kind of planets which move in very oblique and eccentric orbits every way with the greatest freedom, and preserve their motions for an exceeding long time, even where contrary to the course of the planets. Their tail is a very thin and slender vapour, emitted by the head or *nucleus* of the comet when ignited or heated by the sun.

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* According to *Laplace*, the sidereal period of the *Georgian* is 30688.712687 days, [redacted]

## II. OF THE ELONGATIONS, &C. OF THE INTERIOR PLANETS.

Let T, E, *e*, (*Plate* IV. *Fig.* 8,) represent the orbit of the earth; *a*, *w*, *v*, *x*, *f*, *g*, *h*, the orbit of an interior planet, as Mercury or Venus, and S the sun.

Let T represent the earth, S the sun, and *a* Venus at the time of her inferior conjunction; at this time she will disappear like the new moon, because her dark side will be turned towards the earth. While Venus moves from *a* towards *w* she appears to the westward of the sun, and becomes gradually more and more enlightened (having all the different phases of the moon.) When she arrives at *v*, her greatest elongation, she appears half enlightened, like the moon in her first quarter; at this time she shines very bright.* From her inferior to her superior conjunction, viz. from her situation in that part of her orbit which is directly between the earth and the sun as at *a*, to her situation in that part of her orbit in which the sun is between her and the earth; she rises before the sun in the morning, and is called a morning star. From her superior to her inferior conjunction she shines in the evening after the sun sets, and is then called an evening star.

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* The latest writings on the subject of comets are M. Pingré's Cométographie, in two vols. 4to., and Sir Henry Englefield's work, entitled, "On the Determination of the Orbits of Comets. A well written article on Comets may be seen in Dr. Rees' *New Cyclopedia*, together with the elements of ninety-seven of them, and the names of the authors who have calculated their orbits.

†Many interesting particulars respecting the nature of comets, &c. may be learned by referring to the latter end of the third book of Newton's Principia.

From the greatest elongation of Venus when westward of the sun, as at *v*, to her greatest elongation when eastward of the sun as at *g*, she will appear to go forward in her orbit, and describe the arc VWHG amongst the fixed stars; but from *g* to *v* she will appear retrograde†, or return to the point V in the heavens in the order GHWV. For when Venus is at *f*, she will be seen amongst the fixed stars at H, and when at *g*, she will appear at G: when she arrives at *h*, she will again appear at H in the heavens. Hence in a considerable part of her orbit between *f* and *h*, and between *w* and *x*, she will appear nearly in the same point amongst the fixed stars, and at these times is said to be stationary.‡

When a planet appears to move from the neighbourhood of any fixed stars, towards others which lie to the eastward, its motion is said to be *direct;* when it proceeds towards the stars which lie to the west, its motion is *retrograde;* and when it seems not to alter its position amongst the fixed stars, it is said to be stationary.

If the earth stood still at T, the planet Venus would seem to make equal vibrations from the sun each way, forming the equal angles *g*TS and *v*TS, each 47° 48′, her greatest elongation, and the stationary points would always be in the same place in the heavens; but it must be remembered that, while Venus is proceeding in her orbit from *a* towards *x*, the earth is going forward from T towards E; hence the stationary points, and places of conjunction and opposition, vary in every revolution.

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* Venus gives the greatest quantity of light to the earth when her elongation is 39° 44′ *Vince's* Fluxions.

† The stationary and retrograde appearances of the *inferior* planets are neatly illustrated by a small orrery, made and sold by Messrs W. and S. Jones, Mathematical Instrument-makers, Holborn.

‡ This manner of determining the stationary points is the same with that given by Ferguson in his Astronomy, Enfield in his Philosophy, and by many other writers who were neither mathematicians nor practical astronomers. For an accurate and extensive view of this subject see Emerson's Astronomy, Vince's large Astronomy, vol. I. and Delambre's large Astronomy, vol. III.

What has been observed with respect to Venus, may be applied with a little variation to Mercury.

## III. OF THE STATIONARY AND RETROGRADE APPEARANCES OF THE EXTERIOR PLANETS.

Because the earth's orbit is contained within the orbit of Mars, Jupiter, &c. they are seen in all sides of the heavens, and are as often in opposition to the sun as in conjunction with him. Let the circle in which T is situated (*Plate* IV. *Fig.* 8.) represent the orbit of the earth, and that in which M is situated the orbit of Mars. Now, if the earth be at T when Mars is at M, Mars and the sun will be in conjunction, but if the earth be at *t* when Mars is at M, they will be in opposition, viz. the sun will appear in the east when Mars is in the west. If the earth stood still at T, the motion of the planet Mars would always appear *direct;* but the motion of the earth being more rapid than that of Mars, he will be overtaken and passed by the earth. Hence Mars will have two stationary and one retrograde appearance. Suppose the earth to be at E when Mars is at M, he will be seen in the heavens among the fixed stars at *m;* and for some time before the earth has arrived at E, and after it has passed E, he will appear nearly in the same point *m*, viz. he will be *stationary.* While the earth moves through the part E *t e* of its orbit, if Mars stood still at M, he would appear to move in a *retrograde* direction through the arc *m* P *r n*, in the heavens, and would again be stationary at *n;* but if, during the time the earth moves from E to *e*, Mars moves from M to O, the arc of retrogradation would be nearly *m* P *r*.

The same manner of reasoning may be applied to Jupiter and all the superior planets.

## IV. ON SOLAR AND LUNAR ECLIPSES.

*An eclipse of the sun* is occasioned by the dark body of the moon passing between the earth and the sun, or by the shadow of the moon falling on the earth at the place where the observer is situated, hence all the eclipses of the sun happen at the time of the new moon. Thus, let S represent the sun, (*Plate* II. *Fig.* 6.) *m* the moon between the earth and the sun, *a* E G *b* a portion of the earth's orbit, *e* and *f* two places on the surface of the earth. The dark part of the moon's shadow is called the *umbra*, and the light part the *penumbra;* now it is evident that if a spectator be situated in that part of the earth where the *umbra* falls, that is between *e* and *f*, there will be a total eclipse of the sun at that place; at *e* and *f* in the penumbra there will be a *partial* eclipse; and beyond the penumbra there will be no eclipse. As the earth is not always at the same distance from the moon, if an eclipse should happen when the earth is so far from the moon that the lines F *e* and C *f* cross each other before they come to the earth, a spectator situated on the earth, in a direct line between the centres of the sun and moon, would see a ring of light round the dark body of the moon, called an *annular* eclipse: when this happens there can be no total eclipse any where, because the moon's umbra does not reach the earth. People situated in the penumbra will perceive a partial eclipse.

According to M. de Séjour, an eclipse can never be annular longer than 12 min. 24 sec., nor total longer than 7 min 58 sec. If the moon be exactly in her node, the centre of her shadow will pass over the centre of the earth's enlightened disc, and describe a diameter, if the moon has latitude, the centre of her shadow will describe a chord on the circular disc of the earth, varying in length according to her latitude: hence the duration of a solar eclipse depends on the length of the line which the centre of her shadow describes, the proximity of the place to the centre of the earth's disc, and the velocity of the moon's motion.

As the sun is not deprived of any part of his light during a solar eclipse, and the moon's shadow, in its passage over the earth from west to east, only covers a small part of the earth's enlightened hemisphere at once, it is evident that an eclipse of the sun may be invisible to some of the inhabitants of the earth's enlightened hemisphere, and a partial or total eclipse may be seen by others at the same moment of time.

*An eclipse of the moon* is caused by her entering the earth's shadow, and consequently it must happen when she is in opposition to the sun, that is, at the time of full moon, when the earth is between the sun and the moon. Let S represent the sun (*Plate* II. *Fig*. 6.) EG the earth, and *m* the moon in the earth's umbra, having the earth between her and the sun; DEP and HGP the penumbra. Now, the nearer any part of the penumbra is to the umbra, the less light it receives from the sun, as is evident from the figure; and as the moon enters the penumbra before she enters the umbra, she gradually loses her light and appears less brilliant.

The duration of an eclipse of the moon, from her first touching the earth's penumbra to her leaving it, cannot exceed 5 1-2 hours.

The moon cannot continue in the earth's umbra longer than 3¾ hours in any eclipse, neither can she be totally eclipsed for a longer period than 1¾ hour.* As the moon is actually deprived of her light during an eclipse, every inhabitant upon the face of the earth who can see the moon will see the eclipse.

## General Observations on Eclipses.

If the orbit of the earth and that of the moon were both in the same plane, there would be an eclipse of the sun at every new moon, and an eclipse of the moon at every full moon. But the orbit of the moon makes an angle of about 5¼ degrees with the plane of the orbit of the earth, and crosses it in two points called the nodes; now astronomers have calculated that, if the moon be less than 17° 21′ from either node, at the time of new moon, the sun may be eclipsed; or if less than 11° 34′ from either node, at the full moon, the moon may be eclipsed; at all other times, there can be no eclipse, for the shadow of the moon will fall either above or below the earth at the time of new moon; and the shadow of the earth will fall either above or below the moon at the time of full moon. To illustrate this, suppose the right-hand part of the moon's orbit (*Plate* II. *Fig*. 6.) to be elevated above the plane of the paper, or earth's orbit, it is evident that the earth's shadow, at full moon, would fall below the moon; the left-hand part of the moon's orbit at the same time would be depressed below the plane of the paper, and the shadow of the moon, at the time of new moon, would fall below the earth. In this case the moon's nodes would be between E and *a*, and between G and *b*, and there would be no eclipse, either at the full or new moon; but if the part of the moon's orbit between G and *b* be elevated above the plane of the paper, or earth's orbit; the part between E and *a* will be depressed, the line of the moon's nodes will then pass through the centre of the earth and that of the moon, and an eclipse will ensue.† An eclipse of the sun begins on the western side of his disc, and ends on the eastern; and an eclipse of the moon begins on the eastern side of her disc, and ends on the western.

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* Emerson's Astronomy, sect. 7, page 339.

† If you draw the figure on card-paper, and cut out the moon, her shadow and orbit, so as turn on the line *a* E G *b*, &c. the above illustration will be rendered more familiar.

## Number of Eclipses in a Year.

The average number of eclipses in a year is *four*, two of the sun and two of the moon; and as the sun and moon are as long below the horizon of any *particular place* as they are above it, the average number of visible eclipses in a year is two, one of the sun and one of the moon; the lunar eclipse frequently happens a fortnight after the solar one, or the solar one a fortnight after the lunar one.

*The most general number of eclipses, in any year, is four; there are sometimes six eclipses in a year, but there cannot be more than seven, nor fewer than two.*

The reason will appear, by considering that the sun can not pass both the nodes of the moon's orbit more than once a-year, making four eclipses, except he pass one of them in the beginning of the year; in this case he *may* pass the *same* node again a little before the end of the year, because he is about 173* days in passing from one node to the other; therefore he may return to the same node in about 346 days, which is less than a year, making six eclipses. As twelve lunations†, or 354 days from the eclipse in the beginning of the year may produce a new moon before the year is ended, which (on account of the retrograde motion of the moon's node) *may* fall within the solar limit, it is possible for seven eclipses to happen in a year, five of the sun and two of the moon. When the moon changes in either node, she cannot be near enough to the other node at the time of the next full moon to be eclipsed, and in six lunar months afterwards, or about 177 days, she will change near the other node; in this case there can not be more than two eclipses in a year, and both of the sun.

The ecliptic limits of the sun are greater than those of the moon, and hence there will be more solar than lunar eclipses, in the ratio of 17° 21′ to 11° 34′, or nearly of 3 to 2; but more lunar than solar eclipses are seen at any given place, because a lunar eclipse is visible to a whole hemisphere at once, whereas a solar eclipse is visible only to a part, as has been observed before, and therefore there is a greater probability of seeing a lunar than a solar eclipse.

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* The moon's nodes have a retrograde motion of about 19⅓ degrees in a year (see page 147), therefore the sun will have to move $(180 - \frac{19\frac{1}{3}}{2} =)$ 170⅓ degrees from one node to the other. But it has been shown in a preceding note, (see page 36,) that the sun's apparent diurnal motion is about 59′ in a day; hence 59′ : 1 day : : 170⅓° : 173 days.

† That is, 12 times 29 days 12 hours 44 min. 3 sec., or 354 days 8 hours 48 min.

# CHAPTER VII.

## *Of the Calendar.*

THE CALENDAR is a distribution of time, as accommodated to the various uses of life, and contains the division of the year into months, weeks, days, &c. distinguishing the several festivals, and other remarkable days. The manner of reckoning time now in use was instituted by Pope Gregory in 1582, and adopted in England in 1752.

The *Common Notes* for the year, usually given in the almanacs, are, *The Cycle of the Moon*, or Golden Number; *the Epact; the Cycle of the Sun and the Dominical Letter; the number of Direction;* and *the Roman Indiction.**

I. *The Cycle of the Moon* is a period of 19 years, after which the new and full moons fall on the same day of the month as they did at the beginning of the period. Any number of this period is called the *Golden Number.*

### *To find the Golden Number for any Year.*

RULE. Add 1 to the given year, and divide the sum by 19, the remainder is the Golden Number. If there be no remainder, the Golden Number is 19,

*Example.* What is the Golden Number for the year 1825?

$(1825+1)\div 19$ leaves a remainder of 2, which therefore is the Golden Number.

II. *The Epact for any year* is the moon's age at the beginning of that year; that is, the number of days which have elapsed since the last new moon in the preceding year. Its use is to find the *Paschal full moon.*

### *To find the Epact for any Year till* 1900.

RULE. Find the Golden Number and subtract 1 from it, multiply the remainder by 11, and the product will be the Epact; if

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* The Roman Indiction is of no use whatever in the Calendar. It was a period of 15 years, in which the Romans collected a tax from the countries which they had conquered. To find the Roman Indiction add 3 to the year of Christ, and divide the sum by 15, the remainder is the Indiction. Thus, the indiction for 1825 is 13, for $(1825+3)\div 15$ leaves a remainder of 13.

The *Julian Period* appears in the Nautical Almanic for 1825; it is of no use in the calendar; however it may be found by adding 4713 to the year of Christ. Thus, $1825+4713=6538$ the year of the Julian Period.

**the product exceed 30, divide it by 30, and the remainder will be the Epact. When the golden number is 1, the Epact is 29.**

*Example.* What is the epact for the year 1825?

The Golden Number (already found) is 2, hence $(\overline{2-1}\times 11)=11$, which is the Epact.

The Epact for 1824 is 29, the Golden Number being 1.

A Table of the Epacts till the Year 1900.

| Golden Numbers. | Epacts. | Golden Numbers. | Epacts. | Golden Numbers. | Epacts. | Golden Numbers. | Epacts. |
|---|---|---|---|---|---|---|---|
| 1 | XXIX. | 6 | XXV. | 11 | XX. | 16 | XV. |
| 2 | XI. | 7 | VI. | 12 | I. | 17 | XXVI. |
| 3 | XXII. | 8 | XVII. | 13 | XII. | 18 | VII. |
| 4 | III. | 9 | XXVIII. | 14 | XXIII. | 19 | XVIII. |
| 5 | XIV. | 10 | IX. | 15 | IV. | | |

III. ***The Cycle of the Sun* is a period of 28 years, after which the days of the month return to the same days of the week. This cycle has no reference to the apparent motion of the sun, its chief use being to find the Dominical Letter.**

In order to connect the days of the week with the days of the year, the first *seven* letters of the alphabet are chosen to mark the several days of the week. These letters are arranged in such a manner for every year, that the letter A stands for the first of January, B for the second, C for the third, and so on. The seven letters being constantly repeated in their order through all the days of the year, it is plain that the same letter will answer to Sunday throughout the whole year, which is therefore called the *Sunday* Letter.

### *To find the Cycle of the Sun for any Year till* 1900, *and likewise the Sunday Letter.*

Rule. Add 9 to the given year, and divide the sum by 28, the remainder is the year of the solar cycle; if there be no remainder the solar cycle is 28. Then, in the following Table, against the solar cycle you will find the Dominical Letter.

Or, To the given year add its fourth part, and increase the sum by 6, divide the result by 7, and the remainder taken from 7 leaves

F 6, and G 7. In a leap-year this rule always gives the letter answering to the months after February.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ED | 5 | GF | 9 | BA | 13 | DC | 17 | FE | 21 | AG | 25 | CB |
| 2 | C | 6 | E | 10 | G | 14 | B | 18 | D | 22 | F | 26 | A |
| 3 | B | 7 | D | 11 | F | 15 | A | 19 | C | 23 | E | 27 | G |
| 4 | A | 8 | C | 12 | E | 16 | G | 20 | B | 24 | D | 28 | F |

In a leap-year there are two Sunday letters; the left-hand letter is used till the end of February, and the other till the end of the year.

*Example.* What is the Dominical Letter for 1825? $(1825+9$ $\div 28$ leaves a remainder of 14; therefore B is the Sunday Letter.

OR, $1825+\frac{1825}{4}+6=2287$, this divided by 7 leaves 5. Now $7-5=2$ the number of the letter, therefore the letter is B.

The Sunday Letter for the year 1826 is A.

IV. The *Number of Direction* is a number to be added to the 21st of March to show on what day of the month *Easter Sunday* falls. The *earliest Easter* possible is the 22d of March, the *latest* the 25th of April. Within these limits are 35 days, and the number of direction varies from 1 to 35. Thus, if Easter Sunday fall on the 22d of March the number of direction is 1, if on the 23d it is 2; and so on to the 31st, when the number of direction is 10. If Easter Sunday fall on the first of April, the number of direction is 11, if on the 2d it is 12, and so on to the 25th of April, when the number of direction is 35.

A TABLE showing the number of Direction for finding Easter Sunday by the *Golden Number* and *Dominical Letter.*

| | G. N. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dominical Letters. | A | 26 | 19 | 5 | 26 | 12 | 33 | 19 | 12 | 26 | 19 | 5 | 26 | 12 | 5 | 26 | 12 | 33 | 19 | 12 |
| | B | 27 | 13 | 6 | 27 | 13 | 34 | 20 | 13 | 27 | 20 | 6 | 27 | 13 | 6 | 20 | 13 | 34 | 20 | 6 |
| | C | 28 | 14 | 7 | 21 | 14 | 35 | 21 | 7 | 28 | 21 | 7 | 28 | 14 | 7 | 21 | 14 | 28 | 21 | 7 |
| | D | 29 | 15 | 8 | 22 | 15 | 29 | 22 | 8 | 29 | 15 | 8 | 29 | 15 | 1 | 22 | 15 | 29 | 22 | 8 |
| | E | 30 | 16 | 2 | 23 | 16 | 30 | 23 | 9 | 30 | 16 | 9 | 23 | 16 | 2 | 23 | 9 | 30 | 23 | 9 |
| | F | 24 | 17 | 3 | 24 | 10 | 31 | 24 | 10 | 31 | 17 | 10 | 24 | 17 | 3 | 24 | 10 | 31 | 17 | 10 |
| | G | 25 | 18 | 4 | 25 | 11 | 32 | 18 | 11 | 32 | 18 | 4 | 25 | 18 | 4 | 25 | 11 | 32 | 18 | 11 |

*Example.* On what day of the month and in what month does *Easter Sunday* fall in the year 1825?

The Golden number already found is 2, and the Sunday Letter B. Under 2, and in a line with B, in the preceding Table,

**you will find 13, which is the *number of direction*. Easter Sunday falls therefore on the 3d of April.**

*To find the* PASCHAL FULL MOON, *and thence Easter Day by the Epact.*

Add six to the Epact (if this sum exceed 30, thirty must be taken from it, and subtract the sum from 50, the remainder is the *Paschal full moon*, or Easter limit. Add 4 to the number of the Dominical letter, subtract the sum from the limit, and the remainder from the next higher number which will divide even by 7. The last remainder added to the limit will give the number of days from the first of March to Easter Day, both inclusive.

*Example.* Find the Paschal full moon and Easter Day for the year 1825.

The Epact, already found, is 11, then 50—(11+6)=33 Easter limit, or the Paschal full moon. The Dominical letter is B, hence the number of the letter is 2; and 33—(2+4)=27, the next higher number to which, divisible by 7, is 28; therefore (28—27) +33 the limit=34 days from the first of March; hence Easter day is the 3d of April.

A TABLE for finding Easter till the year 1900

| Epacts. | Paschal Full Moons. | Epacts. | Paschal Full Moons. |
|---|---|---|---|
| XXIX. | 13 April E. | IX. | 4 April C. |
| XI. | 2 April A. | XX. | 24 Mar. F. |
| XXII. | 22 Mar. D. | I. | 12 April D. |
| III. | 10 April B. | XII. | 1 April G. |
| XIV. | 30 Mar. E. | XXIII. | 21 Mar. C. |
| XXV. | 18 April C. | IV. | 9 April A. |
| VI. | 7 April F. | XV. | 29 Mar. D. |
| XVII. | 27 Mar. B. | XXVI. | 17 April B. |
| XXVIII. | 15 April G. | VII. | 6 April E. |
|  |  | XVIII. | 26 Mar. A. |

THE USE OF THE TABLE. Find the Epact (by some of the preceding methods), against which, in the Table, is the day of the Paschal full moon, with its corresponding weekly letter.

*Example.* On what day does Easter fall in the year 1825?

The Epact is 11, against which, in the Table, is the 2d of April, the day of the Paschal full moon; and this happens on a Saturday, as indicated by the letter A, B being the Sunday letter for the year; hence Easter Day falls on the 3rd of April.

Having found *Easter Sunday,* all the moveable feasts which depend upon it are known.

| | |
|---|---|
| *Septuagesima Sunday* is 9 weeks | Before Easter. |
| *Sexagesima Sunday* is 8 weeks | |
| *Shrove Sunday* or *Quinquagesima Sunday* is 7 weeks | |
| *Shrove Tuesday* and *Ash Wednesday follow* Quinquagesima Sunday | |
| *Quadragesima Sunday* is 6 weeks | |
| *Palm Sunday* a week | |
| *Good Friday* two days | |
| *Low Sunday* is 1 week | After Easter. |
| *Rogation Sunday* is 5 weeks | |
| *Ascension Day* or *Holy Thursday,* the Thursday following Rogation. | |
| *Whit Sunday* is 7 weeks | |
| *Trinity Sunday* is 8 weeks | |

Then follow all the Sundays after Trinity in order. The Sundays between Ash Wednesday and Easter are called Sundays in Lent; and the Sundays between Easter and Whit Sunday are called Sundays after Easter.

V. By Act of Parliament *Easter Day* is the first Sunday after the full moon which happens upon, or next after, the 21st of March; and if the full moon fall on a Sunday, *Easter Day* is the Sunday After.*

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* The Act of Parliament does not refer to the Astronomical full moon as determined by *exact* calculation, but to the full moon as determined by the *established calendar*. Thus, in the year 1818, the *astronomical* full moon was on Sunday the 22d of March, but the *calendar* full moon was on Saturday the 21st, consequently Easter was the Sunday following, viz. the 22d.

## A TABLE

### FOR FINDING THE MOON'S AGE.

Add the number taken from this table to the day of the month; the sum (rejecting 30, if it exceed 30,) is the age.

| Year. | January. | February. | March. | April. | May. | June. | July. | August. | September. | October. | November. | December. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1823 | 18 | 20 | 19 | 20 | 21 | 22 | 23 | 24 | 26 | 26 | 28 | 28 |
| 1824 | 0 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 8 | 10 | 10 |
| 1825 | 11 | 13 | 12 | 13 | 14 | 15 | 16 | 17 | 19 | 19 | 21 | 21 |
| 1826 | 22 | 24 | 23 | 24 | 25 | 26 | 27 | 28 | 0 | 0 | 2 | 2 |
| 1827 | 3 | 5 | 4 | 5 | 6 | 7 | 8 | 9 | 11 | 11 | 13 | 13 |
| 1828 | 14 | 16 | 15 | 16 | 17 | 18 | 19 | 20 | 22 | 22 | 24 | 24 |
| 1829 | 25 | 27 | 26 | 27 | 28 | 29 | 0 | 1 | 3 | 3 | 5 | 5 |
| 1830 | 6 | 8 | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 14 | 16 | 16 |
| 1831 | 17 | 19 | 18 | 19 | 20 | 21 | 22 | 23 | 25 | 25 | 27 | 27 |
| 1832 | 28 | 0 | 29 | 0 | 1 | 2 | 3 | 4 | 6 | 6 | 8 | 8 |
| 1833 | 9 | 11 | 10 | 11 | 12 | 13 | 14 | 15 | 17 | 17 | 19 | 19 |
| 1834 | 20 | 22 | 21 | 22 | 23 | 24 | 25 | 26 | 28 | 28 | 0 | 0 |
| 1835 | 1 | 3 | 2 | 3 | 4 | 5 | 6 | 7 | 9 | 9 | 11 | 11 |
| 1836 | 12 | 14 | 13 | 14 | 15 | 16 | 17 | 18 | 20 | 20 | 22 | 22 |
| 1837 | 23 | 25 | 24 | 25 | 26 | 27 | 28 | 29 | 1 | 1 | 3 | 3 |
| 1838 | 4 | 6 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 12 | 14 | 14 |
| 1839 | 15 | 17 | 16 | 17 | 18 | 19 | 20 | 21 | 23 | 23 | 25 | 25 |
| 1840 | 26 | 28 | 27 | 28 | 29 | 0 | 1 | 2 | 4 | 4 | 6 | 6 |
| 1841 | 7 | 9 | 8 | 9 | 10 | 11 | 12 | 13 | 15 | 15 | 17 | 17 |

| Moon's age. | High Water. | |
|---|---|---|
| Days. | H: | M. |
| 0 | 0 | 0 |
| 1 | 0 | 36 |
| 2 | 1 | 11 |
| 3 | 1 | 46 |
| 4 | 2 | 21 |
| 5 | 3 | 1 |
| 6 | 3 | 44 |
| 7 | 4 | 37 |
| 8 | 5 | 40 |
| 9 | 6 | 58 |
| 10 | 8 | 14 |
| 11 | 9 | 17 |
| 12 | 10 | 9 |
| 13 | 10 | 53 |
| 14 | 11 | 33 |
| 15 | 12 | 8 |
| 16 | 12 | 45 |
| 17 | 13 | 19 |
| 18 | 13 | 54 |
| 19 | 14 | 30 |
| 20 | 15 | 11 |
| 21 | 15 | 56 |
| 22 | 16 | 51 |
| 23 | 18 | 0 |
| 24 | 19 | 18 |
| 25 | 20 | 31 |
| 26 | 21 | 31 |
| 27 | 22 | 21 |
| 28 | 23 | 3 |
| 29 | 23 | 42 |
| 29½ | 24 | 0 |

**The use of the Table.** *To find the time of new moon.* Subtract the number in the Table, opposite to the given year, and under the given month, from 30.

*Examples.* The time of new moon in February, 1825, is on the 17th (=30– 13); and so on for any other year or month.

*To find the time of full moon.* Subtract the number in the Table, opposite to the given year, and under the given month, from 30; if the remainder be 15, full moon happens on the 30th day of the month; if the remainder exceed 15, the the excess above 15 is the day of the month on which full moon happens; if the remainder fall short of 15, add 15 to it, and the sum will show the day of the month on which full moon will happen.

*Examples.* Full moon happens on June 30th, 1825, for 30—15=15. In January, 1825, full moon falls on the 4th, for 30—11=19, and 19—15=4. In July 1825, full moon falls on the 29th, for 30—16=14, and 14+15=29.

N. B. Though the preceding table be calculated only for 19 years, it will answer till the year 1900, by changing the years at the expiration of 19. Thus instead of 1823, write 1842, and so on in a gradual succession to 1860, without any alteration of the figures under the months; and when these years are elapsed, begin again with 1861, &c. The column in the preceding Table under January, shows the Epacts for the respective years prefixed; and the right-hand column annexed to the moon's age is used in finding the time of high water, in the succeeding problems.

## VI. *Of the Year by the Gregorian Account.*

The year, according to our present mode of reckoning, consists of 365 days for three years together, and every fourth year consists of 366 days, which is called a leap-year, in which the month of February has 29 days. But the centuries which will not divide even by 4, such as 1700, 1800, 1900, are not leap years; 2000 is a leap-year, because 20 centuries are divisible by 4: 2100, 2200, 2300, are not leap years, and so on for succeeding centuries.

Let us examine the accuracy of this. By making every fourth year a leap-year the average length of each year is 365¼ days or 365 days 6 hours; now the solar year consists of 365 days 5 hours 48 minutes, 48 seconds (*Def.* 62), the difference is 11 minutes 12 seconds in 1 year, or 3 days 2 hours 40 minutes in 400 years; but the *Gregorian* mode of reckoning provides for the 3 days, by rejecting the intercalary day in the centuries which are not divisible by 4, as 17, 18, 19, &c. hence the error in the Gregorian calendar is 2 hours 40 minutes in 400 years, or one day in 3600 years: an error which the present generation need not trouble themselves about correcting. To this we may add that the greatest practical astronomers have not agreed definitively on the exact length of the solar or tropical year.

| | D. | H. | M. | S. |
|---|---|---|---|---|
| According to Mayer, this year is . . | 365 | 5 | 48 | 42½ |
| Lalande, . . . | 365 | 5 | 48 | 48 |
| Baron de Zach, . . | 365 | 5 | 48 | 50.9 |
| Delambre, . . . | 365 | 5 | 48 | 51.6 |

From the variety in these numbers, which are of the highest authority, it is manifest that the precise error of the Gregorian calendar is not easy to be determined.

# PART III.

## CONTAINING PROBLEMS PERFORMED BY THE TERRESTRIAL AND CELESTIAL GLOBES.

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## CHAPTER I.

*Problems performed by the Terrestrial Globe.*

### PROBLEM I.

*To find the latitude of any given place.*

**Rule.** Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles: the degree above the place is the latitude. If the place be on the north side of the equator, the latitude is north; if it be on the south side the latitude is south.

On small globes the latitude of a place cannot be found nearer than to about a quarter of a degree. Each degree of the brass meridian on the largest globes is generally divided into three equal parts, each part containing twenty geographical miles; on such globes the latitude may be found to 10′.

**Examples.** What is the latitude of Edinburgh?

*Answer.* 56° north.

2. Required the latitudes of the following places:

Amsterdam
Archangel
Barcelona
Batavia
Bencoolen
Berlin
Cadiz
Canton
Dantzic
Drontheim

Florence
Gibraltar
Hamburgh
Ispahan
Lausanne
Lisbon
Madras
Madrid
Naples
Paris

Philadelphia
Quebec
Rio Janeiro
Stockholm
Turin
Vienna
Warsaw
Wilna
Washington
York.

3. Find all the places on the globe which have no latitude.

4. What is the greatest latitude a place can have?

## PROBLEM II.

*To find all those places which have the same latitude as any given place.*

Rule. Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles, and observe its latitude; turn the globe round, and all places passing under the observed latitude are those required.

All places in the same latitude have the same length of day and night, and the same seasons of the year, though from local circumstances, they may not have the same atmospherical temperature. *See the note, page* 38.

Examples. 1. What places have the same, or nearly the same latitude as Madrid?

*Answer.* Minorca, Naples, Constantinople, Samarcand, Philadelphia, Pekin &c.

2. What inhabitants of the earth have the same length of days as the inhabitants of Edinburgh?

3. What places have nearly the same latitude as London?

4. What inhabitants of the earth have the same seasons of the year as those of Ispahan?

5. Find all places of the earth which have the longest day the same length as at Port Royal in Jamaica.

## PROBLEM III.

*To find the longitude of any place.*

Rule. Bring the given place to the brass meridian, the number of degrees on the equator, reckoning from the meridian passing through London to the brass meridian, is the longitude. If the place lie to the right hand of the meridian passing through London, the longitude is east; if to the left hand, the longitude is west.

On *Adam's* and *Cary's* globes there are two rows of figures above the equator. When the place lies to the right hand of the meridian of London, the longitude must be counted on the upper line; when it lies to the left hand it must be counted on the lower line. *Bardin's* New British Globes have also two rows of figures above the equator, but the lower line is always used in reckoning the longitude.

**Examples.** 1. What is the longitude of Petersburg?

*Answer.* 30¼° east.

2. What is the longitude of Philadelphia?

*Answer.* 75¼° west.

3. Required the longitudes of the following places:

Aberdeen
Alexandria
Barbadoes
Bombay
Botany Bay
Canton
Carlscrona
Cayenne
Civita Vecchia
Constantinople
Copenhagen
Drontheim
Ephesus
Gibraltar
Leghorn
Liverpool
Lisbon
Madras
Masulipatam
Mecca
Nankin
Palermo
Pondicherry
Queda.

4. What is the greatest longitude a place can have?

## PROBLEM IV.

*To find all those places that have the same longitude as a given place.*

Rule. Bring the given place to the brass meridian, then all places under the same edge of the meridian from pole to pole have the same longitude.

All people situated under the same meridian from 66° 28′ north latitude to 66° 28′ south latitude, have noon at the same time; or, if it be one, two, three, or any number of hours before or after noon with one particular place, it will be the same hour with every other place situated under the same meridian.

Examples. 1. What places have the same, or nearly the same longitude as Stockholm?

*Answer.* Dantzic, Presburg, Tarento, the Cape of Good Hope, &c.

2. What places have the same longitude as Alexandria?

3. When it is ten o'clock in the evening at London, what inhabitants of the earth have the same hour?

4. What inhabitants of the earth have midnight when the inhabitants of Jamaica have midnight?

5. What places of the earth have the same longitude as the following places?

London
Quebec
The Sandwich islands

## PROBLEM V.

*To find the latitude and longitude of any place.*

**Rule.** Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles; the degree above the place is the latitude, and the degree on the equator, cut by the brass meridian, is the longitude.

This problem is only an exercise of the *first* and *third.*

**Examples.** 1. What are the latitude and longitude of Petersburg?

*Answer.* Latitude 60° N. longitude 30¼° E.

2. Required the latitudes and longitudes of the following places:

Acapulco
Aleppo
Algiers
Archangel
Belfast
Bergen
Buenos Ayres
Calcutta
Candy
Corinth
Cusco
Copenhagen
Durazzo
Elsinore
Flushing
Cape Guardafui
Hamburgh
Jeddo
Jaffa
Ivica
Lima
Lizard
Lubec
Malacca
Manilla
Medina
Mexico
Mocha
Moscow
Oporto

## PROBLEM VI.

*To find any place on the globe, having the latitude and longitude of that place given.*

**Rule.** Find the longitude of the given place on the equator, and bring it to that part of the brass meridian which is numbered from the equator towards the poles: then under the given latitude, on the brass meridian, you will find the place required.

**Examples.** 1. What place has 151½° east longitude, and 34° south latitude?

*Answer.* Botany Bay.

2. What places have the following latitudes and longitudes?

| Latitudes. | Longitudes. | Latitudes. | Longitudes. |
|---|---|---|---|
| 50° 6' N. | 5° 54' W. | 19° 26' N. | 100° 6' W. |
| 48 12 N. | 16 16 E. | 59 56 N. | 30 19 E. |
| 55 58 N. | 3 12 W. | 0 13 S. | 78 55 W. |
| 52 22 N. | 4 51 E. | 46 55 N. | 69 53 W. |
| 31 13 N. | 29 55 E. | 59 21 N. | 18 4 E. |
| 64 34 N. | 38 58 E. | 8 32 N. | 81 11 E. |
| 34 29 S. | 18 23 E. | 5 9 S. | 119 49 E. |
| 3 49 S. | 102 10 E. | 22 54 S. | 42 44 W. |
| 34 35 S. | 58 31 W. | 36 5 N. | 5 22 W. |
| 38 55 N. | 32 30 E. | 32 38 N. | 17 6 W. |

## PROBLEM VII.

*To find the difference of latitude between any two places.*

RULE. Bring one of the places to that half of the brass meridian which is numbered from the equator towards the poles, and mark the degree above it; then bring the other place to the meridian, and the number of degrees between it and the above mark will be the difference of latitude.

Or, Find the latitudes of both the places (by Prob. I.) then, if the latitude be both north or both south, substract the less latitude from the greater, and the remainder will be the difference of latitude; but, if the latitudes be one north and the other south, add them together, and their sum will be the difference of latitude.

EXAMPLES. 1. What is the difference of latitude between Philadelphia and Petersburg?

*Answer.* 20 degrees.

2. What is the difference of latitude between Madrid and Buenos Ayres?

*Answer.* 75 degrees.

3. Required the difference of latitude between the following places:

London and Rome
Delhi and Cape Comorin
Vera Cruz and Cape Horn
Mexico and Botany Bay
Astracan and Bombay
St. Helena and Manilla
Copenhagen and Toulon
Brest and Inverness
Cadiz and Sierra Leone

Alexandria and the Cape of Good Hope
Pekin and Lima
St. Salvadore and Surinam
Washington and Quebec
Porto Bello and the Straits of Magellan
Trinidad I. and Trincomale
Bencoolen and Calcutta

4. What two places on the globe have the greatest difference of latitude?

## PROBLEM VIII.

### *To find the difference of longitude between any two places.*

Rule. Bring one of the given places to the brass meridian, and mark its longitude on the equator; then bring the other place to the brass meridian, and the number of degrees between its longitude and the above mark, counted on the equator, the nearest way round the globe, will show the difference of longitude.

Or, find the longitudes of both the places (by Prob. III.) then, if the longitudes be both east or both west, subtract the less longitude from the greater, and the remainder will be the difference of longitude; but, if the longitudes be one east and the other west, add them together, and their sum will be the difference of longitude.

When this sum exceeds 180 degrees, take it from 360, and the remainder will be the difference of longitude.

Examples. 1. What is the difference of longitude between Barbadoes and Cape Verd?

*Answer.* 43° 42′.

2. What is the difference of longitude between Buenos Ayres and the Cape of Good Hope?

*Answer.* 76° 54′.

3. What is the difference of longitude between Botany Bay and O'why'ee?

*Answer.* 52° 45′, or 52¾ degrees.

4. Required the difference of longitude between the following places:

Vera Cruz and Canton
Bergen and Bombay
Columbo and Mexico
Juan Fernandes I. and Manilla.
Pelew I. and Ispahan.
Boston in America and Berlin
Constantinople and Batavia
Bermudas I. and I. of Rhodes
Port Patrick and Berne
Mount Heckla and Mount Vesuvius
Mount Ætna and Teneriffe
North Cape and Gibraltar.

5. What is the greatest difference of longitude comprehended between two places?

## PROBLEM IX.

*To find the distance between any two places.*

RULE. The shortest distance between any two places on the earth, is an arc of a great circle contained between the two places. Therefore, lay the graduated edge of the quadrant of altitude over the two places, so that the division marked o may be on one of the places, the degrees on the quadrant comprehended between the two places will give their distance; and if these degrees be multiplied by 60, the product will give the distance in geographical miles; or multiply the degrees by 69.1, and the product will give the distance in English miles.

OR, take the distance between the two places with a pair of compasses, and apply that distance to the equator, which will show how many degrees it contains.

If the distance between the two places should exceed the length of the quadrant, stretch a piece of thread over the two places, and mark their distance; the extent of thread between these marks, applied to the equator, from the meridian of London, will show the number of degrees between the two places.

EXAMPLES. 1. What is the nearest distance between the Lizard and the island of Bermudas?

| | |
|---|---|
| 45¾ distance in degrees. | 45.5 |
| 60 | 69.1 |
| 2700 | 455 |
| 30 | 4095 |
| 15 | 2730 |
| 2745 geographical miles. | 3144.05 English miles. |

2. What is the nearest distance between the island of Bermudas and St. Helena?

| | |
|---|---|
| 73½ distance in degrees. | 73.5 |
| 60 | 69.1 |
| 4380 | 735 |
| 30 | 6615 |
| | 4410 |
| 4410 geographical miles. | |

3. What is the nearest distance between London and Botany Bay?

| | |
|---|---|
| 154 distance in degrees. | 154 |
| 60 | 69.1 |
| 9240 geographical miles. | 154 |
| | 1386 |
| | 924 |
| | 10641.4 English miles. |

4. What is the direct distance between London and Jamaica, in geographical and English miles?

5. What is the extent of Europe in English miles, from Cape Matapan in the Morea, to the North Cape in Lapland?

6. What is the extent of Africa from Cape Verd to Cape Guardafui?

7. What is the extent of South America from Cape Blanco in the west to Cape St. Roque in the east?

8. Suppose the track of a ship to Madras be from the Lizard to St. Anthony, one of the Cape Verd islands, thence to St. Helena, thence to the Cape of Good Hope, thence to the east of the Mauritius, thence a little to the south east of Ceylon, and thence to Madras; how many English miles is the Land's end from Madras?

Simple as the preceding problem may appear in theory, on a superficial view, yet when applied to practice, the difficulties which occur are almost insuperable. In sailing across the trackless ocean, or travelling through extensive and unknown countries, our only guide is the compass, and except two places be situated directly north and south of each other, or upon the equator, though we may travel or sail from one place to the other by the compass, yet we *can not* take the shortest route, as measured by the quadrant of altitude.

To illustrate these observations by examples: *first,* Let two places be situated in latitude 50° north, and differing in longitude 48° 50′, which will nearly correspond with the Land's End and the eastern coast of Newfoundland. The arc of *nearest* distance being that of a great circle, truly calculated by *spherical trigonometry*, is 30° 49′ 6″, equal to $1849\frac{1}{10}$ geographical miles, or $2141\frac{2}{5}$, English miles; but, if a ship steer from the Land's End directly westward, in the latitude of 50° north, till her difference of longitude be 48° 50′, her true distance sailed will be $1883\frac{2}{5}$ geographical miles, or $2181\frac{3}{5}$ English miles, making a circuitous course of $34\frac{3}{10}$ geographical miles, or $40\frac{2}{5}$ English miles. Those who are acquainted with spherical trigonometry and the principles of navigation, particularly *great circle sailing* know that it is *impossible* to conduct a ship exactly on the arc of a great circle, except, as before observed, on the equator or meridian; for, in this example, she must be steered through all the different angles, from N. 70° 49′ 30″ W. to 90 degrees, and continue sailing from thence through all the same varieties of angles, till she arrives at the intended place, where the angle will become 70° 49′ 30″, the same as at first.

*Secondly.* Suppose it were required to find the shortest distance between the Lizard, lat. 49° 57′ N. long. 5° 21′ W. and the island of Bermudas, lat. 32° 35′ N; long. 63° 32′ W. The arc of a great circle contained between the two places will be found, by spherical trigonometry, to be 45° 44′, being 2744 geographical miles, [illegible] miles. See the method of calculating such problems in *Keith's* [illegible] ourth edition, page 313. Now for a ship to run this shortest track [illegible] om the Lizard s. 89° 29′ w. and gradually lessen her course so as to arrive [illegible] das on the rhumb bearing s. 49° 47′ w.; but this, though true in theory, [illegible] cticable; the course and distance must therefore be calculated by *Mercator's* [illegible] g. The direct course by the compass will be found to be s. 68° 9′ w, and the dis[illegible]e upon that course 2800 geographical miles, or 3243 English miles; making a [illegible] tous course of 56 geographical miles, or 65 English miles.

*Hence,* [illegible] *the distance between any two places whose latitudes and longitudes are known, in* [illegible] *to travel or sail from one place to the other, on a direct course by the mariner's* [illegible]*ss, the following methods must be used:*

1. If the [illegible] es be situated on the same meridian, their difference of latitude will be the *ne*[illegible] listance between them in degrees, and the places will be exactly north and [illegible] of each other.

2. If th[illegible] on the equator, their difference of longitude will be the *nearest* distance in degrees, and the places will be exactly east and west of each other.

3. If the places dif[illegible] both in latitudes and longitudes, the distance between them and the point of [illegible] ss on which a person must sail or travel, from the one place to the other, [illegible] ound by *Mercator's Sailing*, as in navigation.

4. If the places be [illegible] the s[illegible] latitude, they will be directly east and west of each other; a[illegible] ence [illegible] ongitude, multiplied by the number of miles which make a de[illegible] itude, according to the following table, will give the distance.

The following table is calculat[illegible] dius is to the length of a degree upon the equator, as the co-sine of the [illegible] de is to the length of a degree in that latitude. See this proportion illustrated in *Keith's Trigonometry*, page 296, fourth edition.

| Deg. Lat. | Geog. Miles. | English Miles. | Deg. Lat. | Geog. Miles. | Eglish Miles. | Deg. Lat. | Geog. Miles. | English Miles. |
|---|---|---|---|---|---|---|---|---|
| 0 | 60.00 | 69.10 | 31 | 51.43 | 59.23 | 61 | 29.09 | 33.50 |
| 1 | 59.99 | 69.09 | 32 | 50.88 | 58.60 | 62 | 28.17 | 32.44 |
| 2 | 59.96 | 69.06 | 33 | 50.32 | 57.95 | 63 | 27.24 | 31.37 |
| 3 | 59.92 | 69.01 | 34 | 49.74 | 57.29 | 64 | 26.30 | 30.29 |
| 4 | 59.85 | 68.93 | 35 | 49.15 | 56.60 | 65 | 25.36 | 29.20 |
| 5 | 59.77 | 68.84 | 36 | 48.54 | 55.90 | 66 | 24.40 | 28.11 |
| 6 | 59.67 | 68.72 | 37 | 47.92 | 55.19 | 67 | 23.44 | 27.06 |
| 7 | 59.55 | 68.58 | 38 | 47.28 | 54.45 | 68 | 22.48 | 25.89 |
| 8 | 59.42 | 68.43 | 39 | 46.63 | 53.70 | 69 | 21.50 | 24.76 |
| 9 | 59.26 | 68.25 | 40 | 45.96 | 52.93 | 70 | 20.52 | 23.63 |
| 10 | 59.09 | 68.05 | 41 | 45.28 | 52.15 | 71 | 19.53 | 22.50 |
| 11 | 58.90 | 67.83 | 42 | 44.59 | 51.35 | 72 | 18.54 | 21.35 |
| 12 | 58.69 | 67.59 | 43 | 43.88 | 50.54 | 73 | 17.54 | 20.20 |
| 13 | 58.46 | 67.33 | 44 | 43.16 | 49.71 | 74 | 16.54 | 19.05 |
| 14 | 58.22 | 67.05 | 45 | 42.43 | 48.86 | 75 | 15.53 | 17.88 |
| 15 | 57.96 | 67.75 | 46 | 41.68 | 48.00 | 76 | 14.52 | 16.72 |
| 16 | 57.68 | 66.42 | 47 | 40.92 | 47.13 | 77 | 13.50 | 15.54 |
| 17 | 57.38 | 66.08 | 48 | 40.15 | 46.24 | 78 | 12.47 | 14.37 |
| 18 | 57.06 | 65.72 | 49 | 39.36 | 45.33 | 79 | 11.45 | 13.18 |
| 19 | 56.73 | 65.34 | 50 | 38.57 | 44.42 | 80 | 10.42 | 12.00 |
| 20 | 56.38 | 64.93 | 51 | 37.76 | 43.49 | 81 | 9.39 | 10.81 |
| 21 | 56.01 | 64.51 | 52 | 36.94 | 42.54 | 82 | 8.35 | 9.62 |
| 22 | 55.63 | 64.07 | 53 | 36.11 | 41.59 | 83 | 7.31 | 8.42 |
| 23 | 55.23 | 63.61 | 54 | 35.27 | 40.62 | 84 | 6.27 | 7.22 |
| 24 | 54.81 | 63.13 | 55 | 34.41 | 39.63 | 85 | 5.23 | 6.02 |
| 25 | 54.38 | 62.63 | 56 | 33.55 | 38.64 | 86 | 4.19 | 4.82 |
| 26 | 53.93 | 62·11 | 57 | 32.68 | 37.63 | 87 | 3.14 | 3.62 |
| 27 | 53.46 | 61.57 | 58 | 31.80 | 36.62 | 88 | 2.09 | 2.41 |
| 28 | 52.98 | 61.01 | 59 | 30.90 | 35.59 | 89 | 1.05 | 1.21 |
| 29 | 52.48 | 60.44 | 60 | 30.00 | 34.55 | 90 | 0.00 | 0.00 |
| 30 | 51.96 | 59.84 | Length of a degree 69.1 English miles. | | | | | |

## PROBLEM X.

*A place being given on the globe, to find all places, which are situated at the same distance from it as any other given place.*

**Rule.** Lay the graduated edge of the quadrant of altitude over the two places, so that the division marked o may be on one of the places, then observe what degree of the quadrant stands over the other place; move the quadrant entirely round, keeping the division marked o in its first situation, and all places which pass under the same degree which was observed to stand over the other place, will be those sought.

**Or,** Place one foot of a pair of compasses in one of the given places, and extend the other foot to the other given place: a circle described from the first place as a centre, with this extent, will pass through all the places sought.

If the distance between the two given places should exceed the length of the quadrant, or the extent of a pair of compasses, stretch a piece of thread over the two places, as in the preceding problem.

Examples. 1. It is required to find all the places on the globe which are situated at the same distance from London as Warsaw.

*Answer.* Koningsburg, Buda, Posega, Alicant, &c.

2. What places are at the same distance from London as Petersburgh?

3. What places are at the same distance from London as Constantinople?

4. What places are at the same distance from Rome as Madrid?

## PROBLEM XI.

*Given the latitude of a place and its distance from a given place, to find that place whereof the latitude is given.*

Rule. If the distance be given in English or geographical miles, turn them into degrees by dividing by 69½ for English miles, or 60 for geographical miles; then put that part of the graduated edge of the quadrant of altitude which is marked o upon the given place, and move the other end eastward or westward (according as the required place lies to the east or west of the given place,) till the degrees of distance cut the given parallel of latitude: under the point of intersection you will find the place sought.

Or, Having reduced the miles into degrees, take the same number of degrees from the equator with a pair of compasses, and with one foot of the compasses in the given place, as a centre, and this extent of degrees, describe a circle on the globe; turn the globe till this circle falls under the given latitude on the brass meridian, and you will find the place required.

Examples. 1. A place in latitude 60° N. is 1320½ English miles from London, and it is situated in E. longitude; required the place.

*Answer.* Divide 1320½ miles by 69½ miles, or, which is the same thing, 2641 half-miles by 139 half-miles, the quotient will give 19 degrees; hence the required place is Petersburg.

2. A place in latitude 32½° N. is 1350 geographical miles from London, and it is situated in W. longitude; required the place.

*Answer.* Divide 1350 by 60 the quotient is 22° 30′, or 22 1-2 degrees; hence the required place is the west point of the Island of Madeira.

3. What place, in E. longitude and 41° N. latitude, is 1520 English miles from London?

4. What place in W. longitude and 13° N. latitude, is 3660 geographical miles from London?

## PROBLEM XII.

*Given the longitude of a place and its distance from a given place, to find that place whereof the longitude is given.*

Rule. If the distance be given in English or geographical miles, turn them into degrees by dividing by 69.1 for English miles, or 60 for geographical miles; then put that part of the graduated edge of the quadrant of altitude which is marked o upon the given place, and move the other end northward or southward (according as the required place lies to the north or south of the given place), till the degrees of distance cut the given longitude: under the point of intersection you will find the place sought.

Or, Having reduced the miles into degrees, take the same number of degrees from the equator with a pair of compasses, and with one foot of the compasses in the given place, as a centre, and this extent of degrees, describe a circle on the globe; bring the given longitude to the brass meridian, and you will find the place, upon the circle, under the brass meridian.

Examples. I. A place in north latitude, and in 60 degrees west longitude, is 4215 English miles from London; required the place.

*Answer.* Divide 4215 by 69.1 the quotient is nearly 61 degrees; hence the required place is Barbadoes.

2. A place in north latitude, and in 75¼ degrees west longitude, is 3120 geographical miles from London; what place is it?

3. A place in 31¼ degrees east longitude, and situated southward of London, is 2211 English miles from it; required the place.

4. A place in 29 degrees east longitude, and situated southward of London, is 1520 English miles from it; required the place.

## PROBLEM XIII.

*To find how many miles make a degree of longitude in any given parallel of latitude.*

**Rule.** Lay the quadrant of altitude parallel to the equator, between any two meridians in the given latitude, which differ in longitude 15 degrees*; the number of degrees intercepted between them multiplied by 4, will give the length of a degree in geographical miles. The geographical miles may be converted into English miles by multiplying by 69.1 and dividing by 60.

**Or,** Take the distance between two meridians, which differ in longitude 15 degrees in the given parallel of latitude, with a pair of compasses: apply this distance to the equator, and observe how many degrees it makes: with which proceed as above.

Since the quadrant of altitude will measure no arc truly but that of a great circle; and a pair of compasses will only measure the chord of an arc, not the arc itself; it follows that the preceding rule cannot be mathematically true, though sufficiently correct for practical purposes. When great exactness is required, recourse must be had to calculation. See the table in the note to problem IX. page 187.

The above rule is founded on a supposition that the number of degrees contained between any two meridians, reckoned on the equator, is to the number of degrees contained between the same meridians, on any parallel of latitude, as the number of geographical miles contained in one degree on the equator, is to the number of geographical miles contained in one degree on the given parallel of latitude. Thus in the latitude of London, two places which differ 15 degrees in longitude, are 9¼ degrees distant by the rule. Hence 15° : 9¼ : : 60m. : 37m., or 15° : 60m. : : 9¼ : 37 m., but 15 are to 60 as 1 to 4, therefore, 1 : 4 : : 9¼ : 37 geographical miles contained in one degree.

**Examples.** 1. How many geographical and English miles make a degree in the latitude of Pekin?

*Answer.* The latitude of Pekin is 40° north; the distance between two meridians in that latitude (which differ in longitude 15 degrees) is 11½ degrees. Now 11½ degrees multiplied by 4, produces 46 geographical miles for the length of a degree of longitude, in the latitude of Pekin; and multiplying 46 by 69.1, and dividing by 60, the quotient is 52.97 English miles.

2. How many miles make a degree in the parallels of latitude wherein the following places are situated?

Surinam
Barbadoes
Havannah
Bermudas
Washington
Quebec
Skalholt
North Cape
Spitzbergen
Cape Verd
Alexandria
Paris.

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* The meridians on Cary's *large* globes are drawn through every *ten degrees.* The rule will answer for these globes, by reading 10 degrees for 15 degrees, and multiplying by 6 instead of 4.

## PROBLEM XIV.

### *To find the bearing of one place from another.*

**Rule.** If both the places be situated on the same parallel of latitude, their bearing is either east or west from each other; if they be situated on the same meridian, they bear north and south from each other: if they be situated on the same rhumb-line,[*] that rhumb-line is their bearing; if they be not situated on the same rhumb-line, lay the quadrant of altitude over the two places, and that rhumb-line which is nearest of being parrallel to the quadrant will be their bearing.

**Or,** If the globe have no rhumb-lines drawn on it, make a small mariner's compass (*such as in Plate* I. *Fig.* 4.) and apply the centre of it to any given place, so that the north and south points may coincide with some meridian; the other points will show the bearings of all the circumjacent places, to the distance of upwards of a thousand miles, if the centrical place be not far distant from the equator.

**Examples.** 1. Which way must a ship steer from the Lizard to the island of Bermudas?

*Answer.* W. S. W.

2. Which way must a ship steer from the Lizard to the island of Madeira?

*Answer.* S. S. W.

3. Required the bearing between London and the following places:

Amsterdam
Athens
Bergen
Berlin
Berne
Brussels
Buda
Copenhagen
Dublin
Edinburgh
Lisbon
Madrid
Naples
Paris.
Petersburg
Prague
Rome
Stockholm
Vienna
Warsaw

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[*] On Adams' globes there are two compasses drawn on the equator, each point of which may be called a rhumb-line, being drawn so as to cut all the meridians in equal angles. One compass is drawn on a vacant place in the Pacific ocean, between America and New-Holland; and another, in a similar manner, in the Atlantic between Africa and South America. There are no rhumb-lines on Cary's, Bardin's, or Addison's globes.

## PROBLEM XV.

### *To find the angle of position between two places.*

Rule. Elevate the north or south pole, according as the latitude is north or south, so many degrees above the horizon as are equal to the latitude of one of the given places; bring that place to the brass meridian, and screw the quadrant of altitude upon the degree over it; next move the quadrant till its graduated edge falls upon the other place; then the number of degrees on the wooden horizon, between the graduated edge of the quadrant and the brass meridian, reckoning towards the elevated pole, is the angle of position between the two places.

Examples. 1. What is the angle of position between London and Prague?

*Answer.* 90 degrees from the north towards the east: the quadrant of altitude will fall upon the east point of the horizon, and pass over or near the following places, viz. Rotterdam, Frankfort, Cracow, Ockzakov, Caffa, south part of the Caspian Sea, Guzerat in India, Madras, and part of the island of Ceylon. Hence all these places have the same angle of position from London.

2. What is the angle of position between London and Port Royal in Jamaica?

*Answer.* 90 degrees from the north towards the west; the quadrant of altitude will fall upon the west point of the horizon.

3. What is the angle of position between Philadelphia and Madrid?

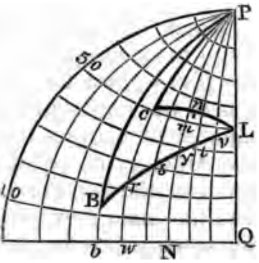
*Answer.* 65 degrees from the north towards the east; the quadrant of altitude will fall between the E.N.E. and N.E. by E. points of the horizon.

4. Required the angles of position between London and the following places:

Amersterdam
Berlin
Berne
Constantinople
Copenhagen
Cairo
Lisbon
Madras
Rome
Stockholm
Petersburg
Quebec.

The preceding problem has been the occasion of many disputes among writers on the globes. Some suppose the angle of position to represent the true bearing of two places, viz. *that point of the compass upon which any person must constantly sail or travel, from the one place to the other;* while others contend that the angle of position between two places is very different from their bearing by the mariner's compass. We shall here endeavour to set the matter in a clear point of view. The following figure represents a quarter of the sphere, stereographically projected on the plane of the meridian with the half meridians and parallels of latitude drawn through every ten degrees; P represents the north pole, and E Q a portion of the equator. Now, by attending to the manner of finding the angle of position, as laid down in the foregoing problem, we shall find that the *quadrant of altitude always forms the base of a spherical triangle, the two sides of which triangle are the complements of the latitudes of the two places, and the vertical angle is their difference of longitude.* The angles at the base of this triangle are the angles of position between the two places.

### I. *When the two places are situated on the same parallel of latitude.*



Let two places L and O be situated in latitude 50° north, and differing in longitude 48° 50′, which will nearly correspond with the Land's End and the eastern coast of Newfoundland (*see the note to Prob.* IX); then OP and LP will be each 40 degrees, the angle OPL, measured by the arc *w* Q, will be 48 50′; whence the arc of nearest distance O *n* L may be found (by case III page 245, *Keith's Trigonometry*) being 30° 39′ 6″, the angle PLO equal to POL, the triangle being isosceles, is 70 49′ 30″; and if *n* be the middle point between L and O, the latitude of that point will be found to be 52° 37′ north, and the angles P *n* L and P *n* O will be right angles. Now, if an indefinite number of points be taken along the edge of the quadrant of altitude, viz. on the arc L *n* O, the angle of position between L and each of these points will be N. 70 49′ 30′ W.; but, if it were possible for a ship to sail along the arc L *n* O, by the compass, her latitude would gradually increase between L and *n*, from 50 N. to 52 37′ N.; and the courses she must steer would vary from 70 49′ 30′ at L, to 90° at *n*. In sailing from *n* to O, she must decrease her latitude from 52° 37′ N. to 50° N and her courses must vary from 90°, or directly west, to 70 49′ 30″; but, if a ship were to sail along the parallel of latitude L *m* O, her course would be invariably due west. Hence it follows that, if two places be situated on the same parallel of latitude, the angle of position between them cannot represent their true bearing by the mariner's compass.

COROLLARY. If the two places were situated on the equator as at *w* and Q, the angle of position between Q and *w*, and between Q and all the intermediate points, as at N, would be 90 degrees. In this case, therefore, and in this *only*, the angle of position shows the true bearing by the compass.

### 2. *If the two places differ both in latitudes and longitudes.*

Let L represent a place in latitude 50° N.; B a place in latitude 13° 30′ N. and let their difference of longitude BPL, measured by the arc *b* Q, be 52° 58′. The angle of position between L and B (calculated by spherical trigonometry) will be found to be S. 68° 57′ W. and the angle of position between B and L will be N. 38 5′ E., whereas, the direct course by the compass from L to B, (calculated by *Mercator's Sailing*) is S. 50° 6′ W., and from B to L it is N 50° 6′ E. If we assume any number of points on the arc L B, the angle of position between L and each of these points will be invariable; viz. P L *v*, P L *t*, P L *y*, P L *s*, P L *r*, &c. are each equal to 68° 57′; while the angle of position between each of these places and L, viz. P *v* L, P *t* L, P *y* L, P *s* L, P *r* L, &c. are continually diminishing. If a ship, therefore, were to sail from L, on a S. 68° 57′ W. course by the mariner's compass, she would never arrive at B; and were she to sail from B, on a N. 38° 5′ E. course by the compass, she would never arrive at L.

*Hence an angle of position between two places cannot represent the bearing, except those places be on the equator, or upon the same meridian.*

## PROBLEM XVI.

X

### *To find the Antœci, Periœci, and Antipodes to the inhabitants of any place.*

Rule. Place the two poles of the globe in the horizon, and bring the given place to the eastern part of the horizon; then, if the given place be in north latitude, observe how many degrees it is to the northward of the east point of the horizon; the same number of degrees to the southward of the east point will show the Antœci; an equal nnmber of degrees, counted from the west point of the horizon towards the north, will show the Periœci; and the same number of degrees, counted towards the south of the west, will point out the Antipodes. If the place be in south latitude, the same rule will serve by reading south for north and the contrary.

OR THUS:

*For the Antœci.* Bring the given place to the brass meridian and observe its latitude, then in the opposite hemisphere, under the same degree of latitude, you will find the Antœci.

*For the Periœci.* Bring the given place to the brass meridian, and set the index of the hour circle to 12, turn the globe half round, or till the index points to the other 12, then under the latitude of the given place you will find the Periœci.

*For the Antipodes.* Bring the given place to the brass meridian, and set the index of the hour circle to 12, turn the globe half round, or till the index points to the other 12, then under the same degree of latitude with the given place, but in the opposite hemisphere, you will find the Antipodes.

Examples. 1. Required the Antœci, Periœci, and Antipodes to the inhabitants of the island of Bermudas.

*Answer.* Their Antœci are situated in Paraguay, a little N. W. of Buenos Ayres; their Periœci in China, N. W. of Nankin; and their Antipodes in the S. W. part of New Holland.

2. Required the Antœci, Periœci, and Antipodes to the inhabitants of the Cape of Good Hope.

3. Captain Cook, in one of his voyages, was in 50 degrees south latitude and 180 degrees of longitude; in what part of Europe were his Antipodes?

4. Required the Antœci to the inhabitants of the Falkland islands.

5. Required the Periœci to the inhabitants of the Phillipine islands.

6. What inhabitants of the earth are Antipodes to those of Buenos Ayres?

## PROBLEM XVII.

*To find at what rate per hour the inhabitants of any given place are carried, from west to east, by the revolution of the earth on its axis.*

Rule. Find how many miles make a degree of longitude in the latitude of the given place (by Problem XIII.) which multiply by 15 for the answer.*

Or, look for the latitude of the given place in the table, Problem IX., against which you will find the number of miles contained in one degree; multiply these miles by 15, and reject two figures from the right hand of the product; the result will be the answer.

Examples. 1. At what rate per hour are the inhabitants of Madrid carried from west to east by the revolution of the earth on its axis?

*Answer.* The latitude of Madrid is about 40° N. where a degree of longitude measures 46 geographical, or nearly 53 English miles (see Example I. Prob. XIII.) Now 46 multiplied by 15 produces 690; and 53 multipled by 15 produces 795; hence the inhabitants of Madrid are carried 690 geographical, or 795 English miles per hour.

*By the Table.*—Against the latitude 40 you will find 45·96 geographical miles, and 52·87 English miles; hence, 45·96 × 15=689·40 and 52·87 × 15=793-05, and thus the required results are 689 geographical or 793 English miles.

Note. The answers found by this rule should be augmented by the 360th part to have the solution accurate, because the earth by its rotation on its axis describes one complete revolution and nearly one degree besides, in the space of a mean solar day: hence the preceding results should be increased by two miles nearly, and thus the correct answer 691 geographical or 795 English miles.

1. At what rate per hour are the inhabitants of the following places carried from west to east by the revolution of the earth on its axis?

Skalholt
Spitzbergen
Petersburg
London
Philadelphia
Cairo
Barbadoes
Quito
Cape of Good Hope
Calcutta
Delhi
Batavia.

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* The reason of this rule is obvious, for if *m* be the number of miles contained in a degree, we have 24 hours : 360° × m. : : 1 hour : the answer; but, 24 is contained 15 times in 360; therefore 1 hour : 15 × m. : : 1 hour : the answer; that is, on a supposition that the earth turns on its axis from west to east in 24 hours; but we have before observed that it turns on its axis in 23 hours 56 min. 4 sec. which will make a small difference not worth notice.

give degrees of longitude; if there be a remainder after dividing by 4, multiply it by 60, and divide the product by four, the quotient will be minutes or miles of longitude. The difference of longitude between the given place and the required places being thus determined, if the hour at the required places be earlier than the hour at the given place, the required places lie so many degrees to the westward of the given place as are equal to the difference of longitude; if the hour at the required places be later than the hour at the given place, the required places lie so many degrees to the eastward of the given place as are equal to the difference of longitude.

EXAMPLES. 1. When it is noon at London, at what place is it half-past eight o'clock in the morning?

*Answer*. The difference of time between London, the given place, and the required places, is 3½ hours, and the time at the required places is *earlier* than that at London; therefore the required places lie 3½ hours westward of London: consequently, by bringing London to the brass meridian, setting the index to 12, and turning the globe eastward till the index has passed over 3½ hours, all the required places will be under the brass meridian, as the eastern coast of Newfoundland, Cayenne, part of Paraguay, &c.

OR, The difference of time between London, the given place, and the required places, is 3 hours 30 min.

3 h. 30 m.
60

4)210 m.

52°—2
60

4)120

30 m.

The difference of longitude between the given place and the required places is 52° 30′. The hour at the required places being earlier than that at the given place, they lie 52° 30′ westward of the given place. Hence, all places situated in 52° 30′ west longitude from London, are the places sought, and will be found to be Cayenne, &c. as above.

2. When it is two o'clock in the afternoon at London, at what place is it ½ past five in the afternoon?

*Answer*. Here the difference of time between London, the given place, and the required places, is 3½ hours; but the time at the required places is *later* than at London. The operation will be the same as in example 1, only the globe must be turned 3½ hours towards the west, because the required places will be in east longitude, or eastward of the given place. The places sought are the Caspian Sea, Western part of Nova Zembla, the island of Socotra, eastern part of Madagascar, &c.

3. When it is ¾ past four in the afternoon at Paris, where is it noon?

4. When it is ¾ past seven in the morning at Ispahan, where is it noon?

5. When it is noon at Madras, where is it ½ past six o'clock in the morning?

6. At sea in latitude 40° north, when it was ten o'clock in the morning by the time-piece, which shows the hour at London, it was exactly nine o'clock in the morning at the ship, by a correct celestial observation. In what part of the ocean was the ship?

7. When it is noon at London, what inhabitants of the earth have midnight?

8. When it is ten o'clock in the morning at London, where is it ten o'clock in the evening?

## PROBLEM XX.

### *To find the sun's longitude (commonly called the sun's place in the ecliptic) and his declination.*

Rule. Look for the given day in the circle of months on the horizon, against which, in the circle of signs, are the sign and degree in which the sun is for that day. Find the same sign and degree in the ecliptic on the surface of the globe; bring the degree of the ecliptic, thus found, to that part of the brass meridian which is numbered from the equator towards the poles, its distance from the equator reckoned on the brass meridian, is the sun's declination.

*This problem may be performed by the celestial globe, using the same rule.*

### Or, by the analemma.*

Bring the analemma to that part of the brass meridian which is numbered from the equator towards the poles, and the degree on the brass meridian, exactly above the day of the month, is the sun's declination. Turn the globe till a point of the ecliptic, corresponding to the day of the month, passes under the degree of the sun's declination, that point will be the sun's longitude or place for the given day. If the sun's declination be *north*, and increasing, the sun's longitude will be somewhere between Aries and Cancer. If the declination be decreasing, the longitude will be between Cancer and Libra. If the sun's declination be *south*, and increasing, the sun's longitude will be between Libra and Capricorn; if the declination be decreasing, the longitude will be between Capricorn and Aries.

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* The Analemma is properly an orthographic projection of the sphere on the plane of the meridian; but what is called the Analemma on the globe is a narrow slip of paper, the length of which is equal to the breadth of the torrid zone. It is pasted on some vacant place on the globe in the torrid zone, and is divided into months, and days of the months, corresponding to the sun's declination for every day in the year. It is divided into two parts; the right-hand part begins at the winter solstice, or December 21st, and is reckoned upwards towards the summer solstice, or June 21st, where the left-hand part begins, which is reckoned downwards in a similar manner, or towards the winter solstice. On Cary's globes the Analemma somewhat resembles the figure 8. It appears to have been drawn in this shape for the convenience of shewing the equation of time, by means of a straight line which passes through the middle of it. The equation of time is placed on the horizon of Bardin's globes.

The sun's longitude and declination are given in the *second* page of every month, in the *Nautical Almanac*, for every day in that month; they are likewise given in *White's Ephemeris*, for every day in the year.

EXAMPLES. 1. What is the sun's longitude and declination on the 13th of April?

*Answer.* The sun's place is 26° in ♈, declination 10° N.

2. Required the sun's place and declination for the following days.

January 21.
February 7.
March 16.
April 8.
May 18.
June 11.
July 11.
August 1.
September 9.
October 16.
November 17.
December 1.

## PROBLEM XXI.

*To place the globe in the same situation* WITH RESPECT TO THE SUN, *as our earth is at the* EQUINOXES, *at the* SUMMER SOLSTICE, *and at the* WINTER SOLSTICE, *and thereby to show the comparative lengths of the longest and shortest days.**

1. FOR THE EQUINOXES. Place the two poles of the globe in the horizon: for at this time the sun has no declination, being in the equinoctial in the heavens, which is an imaginary line standing vertically over the equator on the earth. Now, if we suppose the sun to be fixed, at a considerable distance from the globe, vertically over that point of the brass meridian which is marked ○, it is evident that the wooden horizon will be the boundary of light and darkness on the globe, and that the upper hemisphere will be enlightened from pole to pole.

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* In this problem, as in all others where the pole is elevated to the sun's declination, the sun is supposed to be fixed, and the earth to move on its axis from west to east. The author of this work has a little brass ball made to represent the sun; this ball is fixed upon a strong wire, and when used, slides out of a socket like an acromatic telescope. The socket is made to screw to the brass meridian (of any

Meridians, or lines of longitude, being generally drawn on the globe through every 15 degrees of the equator, the sun will *apparently* pass from one meridian to another in an hour. If you bring the point Aries on the equator to the eastern part of the horizon, the point Libra will be in the western part thereof; and the sun will appear to be setting to the inhabitants of London* and to all places under the same meridian: let the globe be now turned gently on its axis towards the east, the sun will appear to move towards the west, and, as the different places successively enter the dark hemisphere, the sun will appear to be setting in the west. Continue the motion of the globe eastward, till London comes to the western edge of the horizon; the moment it emerges above the horizon, the sun will appear to be rising in the east. If the motion of the globe on its axis be continued eastward, the sun will appear to rise higher and higher, and to move towards the west; when London comes to the brass meridian, the sun will appear at its greatest height; and after London has passed the brass meridian, he will continue his apparent motion westward, and gradually diminish in altitude till London comes to the eastern part of the horizon, when he will again be setting. During this revolution of the earth on its axis, every place on its surface has been twelve hours in the dark hemisphere, and twelve hours in the enlightened hemisphere; consequently the days and nights are equal all over the world; for all the parallels of latitude are divided into two equal parts by the horizon, and in every degree of latitude there are six meridians between the eastern part of the horizon and the brass meridian; each of these meridians answers to one hour, hence half the length of the day is six hours, and the whole length twelve hours.

If any place be brought to the brass meridian, the number of degrees between that place and the horizon (reckoned the nearest way) will be the sun's meridian altitude. Thus, if London be brought to the meridian, the sun will then appear exactly south, and its altitude will be 38½ degrees; the sun's meridian altitude at Philadelphia will be 50 degrees; his meridian altitude at Quito 90 degrees; and here, as in every place on the equator, as the globe turns on its axis, the sun will be vertical. At the Cape of Good Hope the sun will appear due north at noon, and his altitude will be 55½ degrees.

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* The meridian of London is here supposed to pass through the equinoctial point Aries, on the best modern globes.

[illegible] —The summer solstice, to th [illegible] on the 21st of June, wh [illegible] the declination is 23° 2 [illegible] 23½ degrees above the norther [illegible] sign of Cancer in the ecliptic [illegible] that degree of the brass meridi [illegible] the sun be supposed to be fix [illegible] from the globe.

[illegible] it will be seen that th [illegible] two equal parts, the equinocti [illegible] of the horizon, and the eq [illegible] and between the horizo [illegible] the equator) there are si [illegible] an hour apart, consequently th [illegible] long. From the equator north [illegible] the diurnal arcs will exceed th [illegible] than one half of any of the paral [illegible] and of course less tha [illegible] longer than the nights [illegible] the Arctic circle will be [illegible] those inhabitants wil [illegible] as far as the An- [illegible] the *diurnal arcs*: [illegible] parallels of latitude will [illegible] less than one half will [illegible] the Antarctic cir- [illegible] inhabitants, if any, [illegible]

[illegible] latitude, while the [illegible] seen that the arcs [illegible] north of the equa- [illegible] below the horizon, [illegible] the inhabitants of [illegible] south latitude have [illegible] the arcs of those [illegible] of the equator, are [illegible] horizon north of [illegible] who are situated [illegible] those who live north [illegible]

[illegible] them to be [illegible] between the [illegible] of latitude, half the length of the day will be determined in that latitude, the double of which is the length of the day.

1. In the parallel of 20 degrees north latitude, there are six meridians and two thirds more, hence the longest day is 13 hours and 20 minutes; and, in the parallel of 20 degrees south latitude, there are five meridians and one third, hence the shortest day in that latitude is 10 hours and 40 minutes.

2. In the parallel of 30 degrees north latitude, there are seven meridians between the horizon and the brass meridian, hence the longest day is 14 hours; and in the same degree of south latitude there are only five meridians, hence the shortest day in that latitude is ten hours.

3. In the parallel of 50 degrees north latitude there are eight meridians between the horizon and the brass meridian; the longest day is therefore sixteen hours; and in the same degree of south latitude, there are only four meridians; hence the shortest day is eight hours.

4. In the parallel of 60 degrees north latitude, there are 9¼ meridians from the horizon to the brass meredian, hence the longest day is 18½ hours; and in the same degree of south latitude, there are only 2¾ meridians, the length of the shortest day is therefore 5½ hours.

By turning the globe gently round on its axis from west to east, we shall readily perceive that the sun will be vertical to all the inhabitants under the tropic of Cancer, as the places successively pass the brass meridian.

If any place be brought to the brass meridian, the number of degrees between that place and the horizon (reckoned the nearest way) will show the sun's meridian altitude. Thus, at London, the sun's meridian altitude will be found to be about 62 degrees; at Petersburgh 54½ degrees, at Madrid 73 degrees, &c. To the inhabitants of these places the sun appears due south at noon. At Madras the sun's meridian altitude will be 79½ degrees, at the Cape of Good Hope 32 degrees, at Cape Horn 10½ degrees, &c. The sun will appear due north to the inhabitants of these places at noon. If the southern extremity of Spitzbergen, in latitude 76½ north, be brought to that part of the brass meridian which is numbered from the equator towards the poles, the sun's meridian altitude will be 37 degrees, which is its greatest altitude; and if the globe be turned eastward twelve hours or till Spitzbergen comes to that part of the brass meridian which is numbered from the pole towards the equator, the sun's altitude will be ten degrees, which is its least altitude for the day given in the problem. It was shown, in the foregoing part of the problem, that, when the sun is vertically over the equator in the vernal equinox, the north pole begins to be enlightened, consequently the farthe[illegible]e sun apparently proceeds in its course northward, the more [illegible]-light will be diffused over the north polar regions, and the s[illegible] will appear gradually to increase in altitude at the north pole [illegible] the 21st of June, when his greatest height is 23½ degrees; he will then gradually diminish in height till the 23d of September, the time of the autumnal equinox, when he will leave the north pole, and proceed towards the south; consequently the sun has been visible at the north pole for six months.

3. For the Winter Solstice.— The winter solstice, to the inhabitants of north latitude, happens on the 21st of December, when the sun enters Capricorn, at which time his declination is 23° 28′ south. Elevate the south pole 23½ degrees above the southern point of the horizon, bring the sign of Capricorn in the ecliptic to the brass meridian, and over that degree of the brass meridian under which this sign stands let the sun be supposed to be fixed at a considerable distance from the globe.

Here, as at the summer solstice, the days at the equator will be twelve hours long, but the equinoctial point Aries will be in the eastern part of the horizon, and Libra in the western. From the equator southward, as far as the Antarctic circle, the *diurnal arcs* will exceed the *nocturnal arcs*. All the parallels of latitude within the Antarctic circle will be wholly above the horizon. From the equator northward, the *nocturnal arcs* will exceed the *diurnal arcs*. All the parallels of latitude within the Arctic circle will be equally below the horizon. The inhabitants south of the equator will now have their longest day, while those on the north of the equator will have their shortest day.

As the globe turns on its axis from west to east, the sun will be vertical successively to all the inhabitants under the tropic of Capricorn. By bringing any place to the brass meridian, and finding the sun's meridian altitude (as in the foregoing part of the problem), the greatest altitudes will be in south latitude, and the least in the north; contrary to what they were before. Thus, at London, the sun's greatest altitude will be only 15 degrees, instead of 62; and its greatest altitude at Cape Horn will now be 57½ degrees, instead of 10½, as at the summer solstice; hence it appears that the difference between the sun's greatest and least meridian altitude at any place in the temperate zone, is equal to the breadth of the torrid zone, viz. 47 degrees, or more correctly 46° 56′. On the 23d of September, when the sun enters Libra, that is, at the time of the autumnal equinox, the south pole begins to be enlightened, and, as the sun's declination increases southward, he will shine farther over the south pole, and gradually increase in altitude at the pole; for, at all times, his altitude at either pole is equal to his declination. On the 21st of December, the sun will have the greatest south declination, after which his altitude at the south pole will gradually diminish as his declination diminishes; and on the 21st of March, when the sun's declination is nothing, he will appear to skim along the horizon at the south pole, and likewise at the north pole; the sun has therefore been visible at the south pole for six months.

## PROBLEM XXII.

*To place the globe in the same situation,* WITH RESPECT TO THE POLAR STAR *in the heavens, as our earth is to the inhabitants of the equator, &c. viz. to illustrate the three positions of the sphere,* RIGHT, PARALLEL *and* OBLIQUE, *so as to show the comparative length of the longest and shortest days.**

1. **FOR THE RIGHT SPHERE.** The inhabitants who live upon the equator have a right sphere, and the north polar star appears always in (or very near) the horizon. Place the two poles of the globe in the horizon, then the north pole will correspond with the north polar star, and all the heavenly bodies will *appear* to revolve round the earth from east to west, in circles parallel to the equinoctial, according to their different declinations: one half of the starry heavens will be constantly above the horizon, and the other half below, so that the stars will be visible for twelve hours, and invisible for the same space of time; and, in the course of a year, an inhabitant upon the equator may see all the stars in the heavens. The ecliptic being drawn on the terrestrial globe, young students are often led to imagine that the sun apparently moves daily round the earth in the same oblique manner. To correct this false idea, we must suppose the ecliptic to be transferred to the heavens, where it properly points out the sun's apparent annual path amongst the fixed stars. The sun's diurnal path is either over the equator, as at the time of the equinoxes, or in

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* In this problem, and in all others where the pole is elevated to the latitude of a given place, the earth is supposed to be fixed, and the sun to move round it from east to west. When the given place is brought to the brass meridian, the wooden horizon is the true rational horizon of that place, but it does not separate the enlightened part of the globe from the dark part, as in the preceding problem.

Libra, he will again appear to skim along the edge of the horizon, after which he will totally disappear, having been above the horizon for six months. Though the inhabitants at the north pole will lose sight of the sun a short time after the autumnal equinox, yet the twilight will continue for nearly two months; for the sun will not be 18° below the horizon till he enters the 20th of Scorpio, as may be seen by the globe.

After the sun has descended 18° below the horizon, all the stars in the northern hemisphere will become visible, and appear to have a diurnal revolution round the earth from east to west, as the sun appeared to have when he was above the horizon. These stars will not set during the winter half of the year; and the planets, when they are in any of the northern signs, will be visible. The inhabitants under the north polar star have the moon constantly above their horizon during fourteen revolutions of the earth on its axis, and at every full moon which happens, from the 23d of September to the 21st of March, the moon is in some of the northern signs, and consequently visible at the north pole; for the sun being below the horizon at that time, the moon must be above the horizon, because she is always in that sign which is diametrically opposite to the sun at the time of full moon.

When the sun is at his greatest depression below the horizon, being then in Capricorn, the moon is at her FIRST QUARTER in Aries: FULL in Cancer; and at her THIRD QUARTER in Libra: and as the beginning of Aries is the rising point of the ecliptic, Cancer the highest, and Libra the setting point, the moon rises at her FIRST QUARTER in Aries, is most elevated above the horizon, and FULL in Cancer, and sets at the beginning of Libra in her THIRD QUARTER; having been visible for fourteen revolutions of the earth on its axis, viz. during the moon's passage from Aries to Libra. Thus the north pole is supplied one half the winter time with constant moonlight in the sun's absence; and the inhabitants only lose sight of the moon from her THIRD to her FIRST QUARTER, while she gives but little light, and can be of little or no service to them.

3. FOR THE OBLIQUE SPHERE.—Whenever the terrestrial globe is placed in a proper situation with respect to the fixed stars, the pole must be elevated as many degrees above the horizon as are equal to the latitude of the given place, and the north pole of the globe must point to the north polar star in the heavens; for in sailing, or travelling from the equator northward, the north polar star appears to rise higher and higher. On the equator it will appear in the horizon; in ten degrees of north latitude it will be ten degrees above the horizon; in 20° of north latitude it

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declination from [illegible] meridian, and the nort
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the places on the globe above the hori-
dians which pass through the east and west
koning towards the north, are in darkness, not-
are above the horizon: and all places below
day-light, notwithstanding they are below the
n.

## PROBLEM XXIII.

*h and day of the month being given, to find all places
earth where the sun is vertical on that day; those places
the sun does not set, and those places where he does not
on the given day.*

Rule. Find the sun's declination (by Problem XX.) for the given day, and mark it on the brass meridian; turn the globe round on its axis from west to east, and all the places which pass under this mark will have the sun vertical on that day.

*Secondly.* Elevate the north or south pole, according as the sun's declination is north or south, so many degrees above the horizon as are equal to the sun's declination: turn the globe on its axis from west to east; then, to those places which do not descend below the horizon, in that frigid zone near the elevated pole, the sun does not set on the given day: and to those places which do not ascend above the horizon, in that frigid zone adjoining to the depressed pole, the sun does not rise on the given day.

### Or, by the analemma.

Bring the analemma to that part of the brass meridian which is numbered from the equator towards the poles, the degree directly above the day of the month, on the brass meridian, is the sun's declination. Elevate the north or south pole, according as the sun's declination is north or south, so many degrees above the horizon as are equal to the sun's declination; turn the globe on its axis from west to east, then to those places which pass under the sun's declination, on the brass meridian, the sun will be vertical; to those places (in that frigid zone near the elevated pole) which do not go below the horizon, the sun does not set: and to those places (in that frigid zone near the depressed pole) which do not come above the horizon, the sun does not rise on the given day.

will be [illegible] degrees above the horizon : and so on, always increasing in altitude as the latitude increases. Every inhabitant of the earth, except those who live upon the equator, or exactly under the north polar star, has an oblique sphere, viz. the equator cuts the horizon obliquely. By elevating and depressing the poles, in several problems, a young student is sometimes led to imagine that the earth's axis moves northward and southward just as the pole is raised or depressed ; this is a mistake, the earth's axis has no such motion.* In travelling from the equator northward, our horizon varies ; thus, when we are on the equator, the northern point of our horizon is exactly opposite the north polar star ; when we have travelled to ten degrees north latitude, the northern point of our horizon is ten degrees below the pole, and so on : now, the wooden horizon on the terrestrial globe is immoveable, otherwise it ought to be elevated or depressed, and not the pole ; but whether we elevate the pole ten degrees above the horizon, or depress the north point of the horizon ten degrees below the pole, the appearance will be exactly the same.

The latitude of London is about 51½ degrees north : if London be brought to the brass meridian, and the north pole be elevated 51½ degrees above the north point of the wooden horizon, then the wooden horizon will be the true horizon of London ; and, if the artificial globe be placed exactly north and south by a mariner's compass, or by a meridian line, it will have *exactly* the position which the *real globe* has. Now, if we imagine lines to be drawn through every degree† within the torrid zone, parallel to the equator, they will nearly represent the sun's diurnal path on any given day. By comparing these diurnal paths with each other, they will be found to increase in length from the equator northward, and to decrease in length from the equator southward ; consequently, when the sun is north of the equator, the days are increasing in length ; and when south of the equator, the days are decreasing. The sun's meridian altitude for any day may be found by counting the number of degrees from the parallel in which the sun is on that day, towards the horizon, upon the brass meridian ; thus, when the sun is in that parallel of latitude which is seven degrees north of the equator, his meridian altitude will be [illegible] degrees. Though the wooden horizon be the true horizon of the given place, yet it does not separate the enlightened hemisphere of the globe from the dark hemisphere, when the pole is thus elevated. For instance, when the sun is in Aries, and Lon-

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* The earth's axis has a kind of librating motion, called the *nutation*, but this [illegible] be represented by elevating or depressing the pole.

† These lines are drawn on Adams's globes.

### OR, BY THE ANALEMMA.

Find the latitude of the given place (by Problem I.) and mark it on the brass meridian; bring the analemma to the brass meridian, upon which, exactly under the latitude, will be found the two days required.

**EXAMPLES.** 1. On what two days of the year will the sun be vertical at Madras?

*Answer.* On the 25th of April and on the 18th of August.

2. On what two days of the year is the sun vertical at the following places.

Owhyhee
Friendly Isles
Straits of Alass
Penang
Trincomalé
St. Helena
Rio Janeiro
Quito
Barbadoes
Porto Bello
Sierra Leone
Vera Cruz
Manilla
Tinian Isle
Pelew Islands

## PROBLEM XXV.

*The month and the day of the month being given (at any place not in the frigid zones), to find what other day of the year is of the same length.*

RULE. Find the sun's place in the ecliptic for the given day (by Problem XX.), bring it to the brass meridian, and observe the degree above it; turn the globe on its axis till some other point of the ecliptic falls under the same degree of the meridian; find this point of the ecliptic on the horizon, and directly against it you will find the day of the month required.

*This Problem may be performed by the celestial globe in the same manner.*

### OR, BY THE ANALEMMA.

Look for the given day of the month on the analemma, and adjoining it you will find the required day of the month.

### OR, WITHOUT A GLOBE.

Any two days of the year which are of the same length, will be an equal number of days from the longest or shortest day. Hence, Examples. 1. Find all places of the earth where the sun is vertical on the 11th of May, those places in the north frigid zone where the sun does not set, and those places in the south frigid zone where he does not rise.

*Answer.* The sun is vertical at St. Anthony, one of the Cape Verd islands, the Virgin islands, south of St. Domingo, Jamaica, Golconda, &c. All the places within eighteen degrees of the north pole will have constant day; and those (if any) within eighteen degrees of the south pole will have constant night.

2. Whether does the sun shine over the north or south pole on the 27th of October, to what places will he be vertical at noon, what inhabitants of the earth will have the sun below their horizon during several revolutions, and to what part of the globe will the sun never set on that day?

3. Find all the places of the earth where the inhabitants have no shadow when the sun is on their meridian on the first of June.

4. What inhabitants of the earth have their shadows directed to every point of the compass during a revolution of the earth on its axis on the 15th of July?

5. How far does the sun shine over the south pole on the 14th of November, what places in the north frigid zone are in perpetual darkness, and to what places is the sun vertical?

6. Find all places of the earth where the moon will be vertical on the 3rd of June 1825.*.

## PROBLEM XXIV.

*A place being given in the torrid zone, to find those two days of the year on which the sun will be vertical at that place.*

Rule. Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles, and mark its latitude; turn the globe on its axis, and observe what two points of the ecliptic pass under that latitude: seek those points of the ecliptic in the circle of signs on the horizon, and exactly against them, in the circle of months, stand the days required.

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* To perform this example, find the moon's declination on the given day in the Nautical Almanac, or White's Ephemeris, and mark it on the brass meridian, all places passing under that degree of declination will have the moon vertical, or nearly so, on the given day. The moon's declination at midnight on the third of [redacted]

### OR, BY THE ANALEMMA.

Find the latitude of the given place (by Problem I.) and mark it on the brass meridian; bring the analemma to the brass meridian, upon which, exactly under the latitude, will be found the two days required.

EXAMPLES. 1. On what two days of the year will the sun be vertical at Madras?

*Answer.* On the 25th of April and on the 18th of August.

2. On what two days of the year is the sun vertical at the following places.

Owhyhee
Friendly Isles
Straits of Alass
Penang
Trincomalé
St. Helena
Rio Janeiro
Quito
Barbadoes
Porto Bello
Sierra Leone
Vera Cruz
Manilla
Tinian Isle
Pelew Islands

## PROBLEM XXV.

*The month and the day of the month being given (at any place not in the frigid zones), to find what other day of the year is of the same length.*

RULE. Find the sun's place in the ecliptic for the given day (by Problem XX.), bring it to the brass meridian, and observe the degree above it; turn the globe on its axis till some other point of the ecliptic falls under the same degree of the meridian; find this point of the ecliptic on the horizon, and directly against it you will find the day of the month required.

*This Problem may be performed by the celestial globe in the same manner.*

### OR, BY THE ANALEMMA.

Look for the given day of the month on the analemma, and adjoining it you will find the required day of the month.

### OR, WITHOUT A GLOBE.

Any two days of the year which are of the same length, will be an equal number of days from the longest or shortest day. Hence, whatever number of days the given day is before the longest or shortest day, just so many days will the required day be after the longest or shortest day, *et contra.*

**Examples.** 1. What day of the year is of the same length as the 25th of April?

*Answer.* The 18th of August.

2. What day of the year is of the same length as the 25th of May?

3. If the sun rise at four o'clock in the morning at London on the 17th of July, on what other day of the year will it rise at the same hour?

4. If the sun set at seven o'clock in the evening at London on the 24th of August, on what other day of the year will it set at the same hour?

5. If the sun's meridian altitude be 90° at Trincomalé, in the Island of Ceylon, on the 12th of April, on what other day of the year will the meridian altitude be the same?

6. If the sun's meridian altitude at London on the 25th of April be 51° 35′, on what other day of the year will the meridian altitude be the same?

7. If the sun be vertical at any place on the 15th of April, how many days will elapse before he is vertical a second time at that place?

8. If the sun be vertical at any place on the 20th of August, how many days will elapse before he is vertical a second time at that place?

## PROBLEM XXVI.

*The month, day, and hour of the day being given, to find where the sun is vertical at that instant.*

**Rule.** Find the sun's declination (by Problem XX.), and mark it on the brass meridian; bring the given place to the brass meridian, and set the index of the hour-circle to twelve; then, if the given time be before noon, turn the globe westward as many hours as it wants of noon; but, if the given time be past noon, turn the globe *eastward* as many hours as the time is past noon; the place exactly under the degree of the sun's declination will be that sought.

**Examples.** 1. When it is forty minutes past six o'clock in the morning at London on the 25th of April, where is the sun vertical?

*Answer.* Here the given time is five hours twenty minutes before noon; hence the globe must be turned towards the *west* till the index has passed over five hours twenty minutes,* and under the sun's declination on the brass meridian you will find Madras, the place required.

2. When it is four o'clock in the afternoon at London on the 18th of August, where is the sun vertical?

*Answer.* Here the given time is four hours past noon; hence the globe must be turned towards the *east*, till the index has passed over four hours, then, under the sun's declination, you will find Barbadoes, the place required.

3. When it is three o'clock in the afternoon at London on the 4th of January, where is the sun vertical?

4. When it is three o'clock in the morning at London, on the 11th of April, where is the sun vertical?

5. When it is thirty seven minutes past one o'clock in the afternoon at the Cape of Good Hope on the 5th of February, where is the sun vertical?

6. When it is eleven minutes past one o'clock in the afternoon at London on the 29th of April, where is the sun vertical?

7. When it is twenty minutes past five o'clock in the afternoon at Philadelphia on the 18th of May, where is the sun vertical?

8. When it is nine o'clock in the morning at Calcutta on the 11th of April, where is the sun vertical?

## PROBLEM XXVII.

*The month, day, and hour of the day at any place being given, to find all those places of the earth where the sun is rising, those places where the sun is setting, those places that have noon, that particular place where the sun is vertical, those places that have morning twilight, those places that have evening twilight, and those places that have midnight.*

**Rule.** Find the sun's declination (by Problem XX.) and mark it on the brass meridian; elevate the north or south pole, according as the sun's declination is north or south, so many degress above the horizon as are equal to the sun's declination; bring the given place to the brass meridian, and set the index of the hour circle to twelve; then, if the given time be before noon, turn the globe *westward* as many hours as it wants of noon; but, if the given time be past noon, turn the globe eastward as many hours as the time is past noon: keep the globe in this position; then all places along the western edge of the horizon have the sun rising; those places along the eastern edge have the sun setting; those under the brass meridian above the horizon, have noon; that particular place which stands under the sun's declination on the brass meridian, has the sun vertical: all places below the western edge of the horizon, within eighteen degrees, have morning twilight; those places which are below the eastern edge of the horizon, within eighteen degrees, have evening twilight; all places under the brass meridian below the horizon, have midnight; all the places above the horizon have day, and those below it have night or twilight.

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* If the hour circle be not divided to twenty minutes, turn the globe westward till the index has passed over five hours and a quarter; then, by turning it a degree and a quarter farther to the west (answering to five minutes of time), the solution will be exact. See the note to the next Problem. The degrees must be counted on the equator.

EXAMPLES. 1. When it is fifty-two minutes past four o'clock in the morning at London on the 5th of March, find all places of the earth where the sun is rising, setting, &c. &c.

*Answer.* The sun's declination will be found to be 6¼° south; therefore, elevate the south pole 6¼° above the horizon. The given time being seven hours eight minutes before noon (= 12h.—4h. 52m.) the globe must be turned towards the *west*, till the index has passed over seven hours eight minutes.* Let the globe be fixed in this position; then,

*The sun is rising* at the western part of the White Sea, Petersburg, Morea in Turkey, &c.

*Setting* at the eastern coast of Kamtschatka, Jesus Island, Palmerston Island, &c. between the Friendly and Society Islands.

*Noon* at the late Baikal in Irkoutsk, Cochin China, Cambodia, Sunda Islands, &c.

*Vertical* at Batavia.

*Morning twilight* at Sweden, part of Germany, the southern part of Italy, Sicily, the western coast of Africa along the Æthiopean Ocean, &c.

*Evening twilight* at the north west extremity of North America, the Sandwich Islands, Society Islands, &c.

*Midnight* at Labrador, New-York, western part of St. Domingo, Chili, and the western coast of South America.

*Day* at the eastern part of Russia in Europe, Turkey, Egypt, the Cape of Good Hope, and all the eastern part of Africa, almost the whole of Asia, &c.

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* The hour-circles, in general, are not divided into parts less than a quarter of an hour, but the odd minutes are easily reckoned. In this example, having turned the globe westward till the index has passed over seven hours; then, because four minutes of time make one degree, reckon *two* degrees on the equator eastward, and turn the globe till they pass under the brass meridian.

*Night* at the whole of North and South America, the western part of Africa, the British Isles, France, Spain, Portugal, &c.

2. When it is four o'clock in the afternoon at London on the 25th of April, where is the sun rising, setting, &c. &c.?

*Answer.* The sun's declination being 13° north, the north pole must be elevated 13° above the horizon*; and as the given time is four o'clock in the afternoon, the globe must be turned four hours towards the *east;* then the sun will be *rising* at Owhyhee, &c. *setting* at the Cape of Good Hope, &c.; it will be *noon* at Buenos Ayres, &c. the sun will be *vertical* at Barbadoes, and, following the directions in the Problem, all the other places are readily found.

3. When it is ten o'clock in the morning at London on the longest day, to what countries is the sun rising, setting, &c. &c.?

4. When it is ten o'clock in the afternoon at Botany Bay on the 15th of October, where is the sun rising, setting, &c. &c.

5. When is it seven o'clock in the morning at Washington on the 17th of February, where is the sun rising, setting, &c. &c.?

6. When it is midnight at the Cape of Good Hope on the 27th of July, where is the sun rising, setting, &c. &c.

## PROBLEM XXVIII.

*To find the time of the sun's rising and setting, and length of the day and night, at any place not in the frigid zones.*

**Rule.** Find the sun's declination (by Problem XX.) and elevate the north or south pole, according as the declination is north or south, so many degrees above the horizon as are equal to the sun's declination; bring the given place to the brass meridian, and set the index of the hour-circle to twelve; turn the globe *eastward* till the given place comes to the eastern semi-circle of the horizon, and the number of hours passed over by the index will be the time of the sun's setting: deduct these hours from twelve, and you have the time of the sun's rising; because the sun rises as many hours before twelve as it sets after twelve. Double the time of the sun's setting gives the length of the day, and double the time of rising gives the length of the night.

By the same rule, the length of the *longest* day, at all places not in the frigid zones, may be readily found; for the longest day at all places in north latitude is on the 21st of June, or when the sun enters Cancer; and the longest day at all places in

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* If the hour-circle of the globe be placed *above* the brass meridian, it must be unscrewed and removed from the pole; the hours may then be counted on the equator. See the note to definition 19. p. 29.

[illegible] the sun enters the sign of Cap-

[illegible] north or [illegible] south, so many [illegible] latitude: find the [illegible] the brass [illegible] turn the [illegible] western semi- [illegible] over by the [illegible] hours taken [illegible]

## [illegible] BY THE ANALEMMA.

[illegible] latitude of the given place, and elevate the north or south pole according as the latitude is north or south, the same number of degrees above the horizon: bring the middle of the [illegible]

[illegible] following [illegible] length

[illegible] Hope, 7 Dec.

[illegible] January

[illegible] December

[illegible] October

Constantinople, 18th Aug.

3. Find the time the sun rises and sets at every place on the surface of the globe on the 21st of March, and likewise on the 23d of September.

4. Required the length of the longest day and shortest night at the following places:

London
Petersburg
Aberdeen
Dublin
Glasgow
Paris
Vienna
Berlin
Buenos Ayres
Botany Bay
Pekin
Cape Horn
Washington
Cape of Good Hope
Copenhagen.

5. Required the length of the shortest day and longest night at the following places:

London
Archangel
O Taheitee
Quebec
Lima
Mexico
St. Helena
Alexandria
Paris
Owhyhee
Lisbon
Falkland Islands.

6. How much longer is the 21st of June at Petersburg than at Alexandria?

7. How much longer is the 21st of December at Alexandria than at Petersburg?

8. At what time does the sun rise and set at Spitzbergen on the 5th of April?

## PROBLEM XXIX.

*The length of the day at any place, not in the frigid zones, being given, to find the sun's declination and the day of the month.*

Rule. Bring the given place to the brass meridian, and set the index to twelve: turn the globe eastward till the index has passed over as many hours as are equal to half the length of the day; keep the globe from revolving on its axis, and elevate or depress one of the poles till the given place exactly coincides with the eastern semi-circle of the horizon; the distance of the elevated pole from the horizon will be the sun's declination: mark the sun's declination, thus found, on the brass meridian: turn the globe on its axis, and observe what two points of the ecliptic pass under this mark; seek those points in the circle of signs on the horizon, and exactly against them, in the circle of months, stand the days of the months required.

## OR,

Bring the meridian passing through Libra* to coincide with the brass meridian, elevate the pole to the latitude of the place, and set the index of the hour-circle to twelve; turn the globe eastward till the index has passed over as many hours as are equal to half the length of the day, and mark where the meridian passing through Libra is cut by the eastern semi-circle of the horizon; bring this mark to the brass meridian,† and the degree above it is the sun's declination; with which proceed as above.

## OR, BY THE ANALEMMA.

Bring the middle of the analemma to the brass meridian, elevate the pole to the latitude of the place, and set the index of the hour-circle to twelve; turn the globe eastward till the index has passed over as many hours as are equal to half the length of the day; the two days, on the analemma, which are cut by the eastern semi-circle of the horizon, will be the days required; and, by bringing the analemma to the brass meridian, the sun's declination will stand exactly above these days.

EXAMPLES. 1. What two days in the year are each sixteen hours long at London, and what is the sun's declination?

*Answer.* The 24th of May and the 17th of July. The sun's declination is about 21° north.

2. What two days of the year are each fourteen hours long at London?

3. On what two days of the year does the sun set at half-past seven o'clock at Edinburgh?

4. On what two days of the year does the sun rise at four o'clock at Petersburg?

5. What two nights of the year are each ten hours long at Copenhagen?

6. What day of the year at London is sixteen hours and a half long?

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[*] Any meridian will answer the purpose, and the globe may be turned either eastward or westward; but it is the most convenient to turn it eastward, because the brass meridian is graduated on the east side.

[†] If Adams' globes be used, the meridian passing through Libra is graduated like the brass meridian, and the declination is found at once.

## PROBLEM XXX.

*To find the length of the longest day at any place in the north* frigid zone.*

**Rule.** Bring the given place to the northern point of the horizon (by elevating or depressing the pole), and observe its distance from the north pole on the brass meridian; count the same number of degrees on the brass meridian from the equator, towards the north pole, and mark the place where the reckoning ends: turn the globe on its axis, and observe what two points of the ecliptic pass under the above mark; find those points of the ecliptic in the circle of signs on the horizon, and exactly against them, in the circle of months, you will find the days on which the longest day begins and ends. The day preceding the 21st of June is that on which the longest day begins at the given place, and the day following the 21st of June is that on which the longest day ends: the time between these days is the length of the longest day.

### Or, by the Analemma.

Bring the given place to that part of the brass meridian which is numbered from the north pole towards the equator, and observe its distance in degrees from the pole; count the same number of degrees on the brass meridian from the equator towards the north pole, and mark where the reckoning ends; bring the analemma to the brass meridian, and the two days which stand under the above mark will point out the beginning and end of the longest day.

**Examples.** 1. What is the length of the longest day at the North Cape, in the island of Maggeroe, in latitude 71° 30′ north?

*Answer.* The place is 18½° from the pole; the longest day begins on the 14th of May, and ends on the 30th of July; the day is therefore seventy-seven days long, that is, the sun does not set during seventy-seven revolutions of the earth on its axis.

2. What is the length of the longest day in the north of Spitzbergen, and on what day does it begin and end?

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* The south frigid zone being uninhabited (at least we know of no inhabitants) the Problem is not applied to that zone; however, the rule is general, reading south for north, and 21st of December for the 21st of June.

3. What is the length of the longest day at the northern extremity of Nova Zembla ?

4. What is the length of the longest day at the north pole, and on what day does it begin and end ?

## PROBLEM XXXI.

*To find the length of the longest night at any place in the north* frigid zone.*

Rule. Bring the given place to the northern point of the horizon (by elevating or depressing the pole), and observe its distance from the north pole on the brass meridian ; count the same number of degrees on the brass meridian from the equator towards the south pole, and mark the place where the reckoning ends ; turn the globe on its axis, and observe what two points of the ecliptic pass under the above mark ; find those points of the ecliptic in the circle of signs on the horizon, and exactly against them in the circle of months, you will find the days on which the longest night begins and ends. The day preceding the 21st of December is that on which the longest night begins at the given place, and the day following the 21st of December is that on which the longest night ends : the time between these days is the length of the longest night.

### Or, by the analemma.

Bring the given place to that part of the brass meridian which is numbered from the north pole towards the equator, and observe its distance in degrees from the pole ; count the same number of degrees on the brass meridian from the equator towards the south pole, and mark where the reckoning ends ; bring the analemma to the brass meridian, and the two days which stand under the above mark will point out the beginning and end of the longest night.

Examples. 1. What is the length of the longest night at the North Cape, in the island of Maggeroe, in latitude 71° 30′ north ?

*Answer.* The place is 18½° from the pole ; the longest night begins on the 16th of November, and ends on the 27th of January : the night is therefore seventy-three days long, that is, the sun does not rise during seventy-three revolutions of the earth on its axis.

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* This Problem is equally applicable to any place in the south frigid zone, and the rule will be general by reading south for north, and the contrary ; likewise, instead of the 21st of December read the 21st of June.

2. What is the length of the longest night at the north of Spitzbergen?

3. The Dutch wintered in Nova Zembla, latitude 76 degrees north, in the year 1596; on what day of the month did they lose sight of the sun; on what day of the month did he appear again; and how many days were they deprived of his appearance, setting aside the effect of his refraction?

4. For how many days are the inhabitants of the northernmost extremity of Russia deprived of a sight of the sun?

## PROBLEM XXXII.

### *To find the number of days which the sun rises and sets at any place on the north* frigid zone.*

Rule. Bring the given place to the northern point of the horizon (by elevating or depressing the pole), and observe its distance from the north pole on the brass meridian; count the same number of degrees on the brass meridian from the equator towards the poles northward and southward, and make marks where the reckoning ends; observe what two points of the ecliptic nearest to Aries pass under the above marks; these points will show (upon the horizon) the end of the longest night and the beginning of the longest day; during the time between these days the sun will rise and set every twenty-four hours; next observe what two points of the ecliptic nearest to Libra, pass under the marks on the brass meridian; find these points, as before, in the circle of signs, and against them you will find the day on which the longest night begins; during the time between these days the sun will rise and set every twenty-four hours.

Or,

Find the length of the longest day at the given place (by Prob. XXX.) and the length of the longest night (by Prob. XXXI), add these together, and subtract the sum from 365 days, the length of the year, the remainder will show the number of days which the sun rises and sets at that place.

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* The same might be found for a place in the south frigid zone, were that zone inhabited.

### OR, BY THE ANALEMMA.

Find how many degrees the given place is from the north pole, and mark those degrees upon the brass meridian on both sides of the equator; observe what four days on the analemma stand under the marks on the brass meridian; the time between those two days on the left-hand part of the analemma (reckoning towards the north pole) will be the number of days on which the sun rises and sets, between the end of the longest night and the beginning of the longest day: and the time between the two days on the right-hand part of the analemma (reckoning towards the south pole) will be the number of days on which the sun rises and sets, between the end of the longest day and the beginning of the longest night.

**EXAMPLES.** 1. How many days in the year does the sun rise and set at the North Cape, in the island of Maggeroe, in latitude 71° 30′ north?

*Answer.* The place is 18½° from the pole, the two points in the ecliptic, *nearest to Aries*, which pass under 18½° on the brass meridian, are 8° in ♒, answering to the 27th of January, and 24° in ♉, answering the 14th of May. Hence the sun rises and sets for 107 days, viz. from the end of the longest night, which happens on the 27th of January, to the beginning of the longest day, which happens on the 14th of May. *Secondly*, the two points in the ecliptic *nearest to Libra*, which pass under 18½° on the brass meridian, are 8° in ♌, answering to the 30th of July, and 24° in ♏, answering to the 15th of November. Hence the sun rises and sets for 108 days, viz. from the end of the longest day, which happens on the 30th of July, to the beginning of the longest night, which happens on the 15th of November; so that the whole time of the sun's rising and setting is 215 days.

OR, THUS:

The length of the longest day, by Example 1st. Prob XXX. is 77 days; the length of the longest night, by Example 1st, Prob. XXXI. is 73 days; the sum of these is 150, which deducted from 365, leaves 215 days as above.

2. How many days in the year does the sun rise and set at the north of Spitzbergen?

3. How many days does the sun rise and set at Greenland, in latitude 75° north?

4. How many days does the sun rise and set at the northern extremity of Russia in Asia?

## PROBLEM XXXIII.

*To find in what degree of north latitude, on any day between the 21st of March and 21st of June, or in what degree of south latitude, on any day between the 23d of September and the 21st of December, the sun begins to shine constantly without setting; and also in what latitude in the opposite hemisphere he begins to be totally absent.*

Rule. Find the sun's declination (by Problem XX.), and count the same number of degrees from the north pole towards the equator, if the declination be north, or from the south pole, if it be south, and mark the point where the reckoning ends: turn the globe on its axis, and all places passing under this mark are those in which the sun begins to shine constantly without setting at that time: the same number of degrees from the contrary pole will point out all the places where twilight or total darkness begins.

Examples. 1. In what latitude north, and at what places, does the sun begin to shine without setting during several revolutions of the earth on its axis, on the 14th of May?

*Answer.* The sun's declination is 18½° north, therefore all places in latitude 71½° north, will be the places sought, viz. the North Cape in Lapland, the southern part of Nova Zembla, Icy Cape, &c.

2. In what latitude south does the sun begin to shine without setting on the 18th of October, and in what latitude north does he begin to be totally absent?

*Answer.* The sun's declination is 10° south, therefore he begins to shine constantly in latitude 80° south, where there are no inhabitants known, and to be totally absent in latitude 80° north, viz. at Spitzbergen.

3. In what latitude does the sun begin to shine without setting on the 20th of April?

4. In what latitude north does the sun begin to shine without setting on the 1st of June, and in what degree of south latitude does he begin to be totally absent?

## PROBLEM XXXIV.

*Any number of days, not exceeding 182, being given, to find the parallel of north latitude in which the sun does not set for that time.*

Rule. Count half the number of days from the 21st of June on the horizon, eastward or westward, and opposite to the last day you will find the sun's place in the circle of signs: look for the sign and degree on the ecliptic, which bring to the brass meridian, and observe the sun's declination; reckon the same number of degrees from the north pole (on that part of the brass meridian which is numbered from the equator towards the poles) and you will have the latitude sought.

Examples. 1. In what degree of north latitude, and at what place does the sun continue above the horizon for seventy-seven days?

*Answer.* Half the number of days is 38½, and if reckoned backward, or towards the east, from the 21st of June, will answer to the 14th of May; and if counted forward, or towards the west, will answer to the 30th of July; on either of which days the sun's declination is 18½ degrees north, consequently the places sought are 18½ degrees from the north pole, or in latitude 71½ degrees north; answering to the North Cape in Lapland, the south part of Nova Zembla, Icy Cape, &c.

2. In what degree of north latitude is the longest day 134 days, or 3216 hours in length?

3. In what degree of north latitude does the sun continue above the horizon for 2160 hours?

4. In what degree of north latitude does the sun continue above the horizon for 1152 hours?

## PROBLEM XXXV.

### *To find the beginning, end, and duration of twilight at any place on any given day.*

Rule. Find the sun's declination for the given day (by Problem XX.), and elevate the north or south pole, according as the declination is north or south, so many degrees above the horizon as are equal to the sun's declination; screw the quadrant of altitude on the brass meridian, over the degree of the sun's declination; bring the given place to the brass meridian, and set the index of the hour-circle to twelve; turn the globe eastward till the given place comes to the horizon, and the hours passed over by the index, will show the time of the sun's setting, or the beginning of evening twilight: continue the motion of the globe eastward, till the given place coincides with 18° on the quadrant of altitude below* the horizon, and the hours passed over by the index, from

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* The quadrant of altitude belonging to our modern globes is always graduated to 18 degrees below the horizon.

12, will show when evening twilight ends. The time when evening twilight ends, subtracted from 12, will show the beginning of morning twilight.

### Or thus:

Elevate the north or south pole, according as the latitude of the given place is north or south, so many degrees above the horizon as are equal to the latitude; find the sun's place in the ecliptic, bring it to the brass meridian, set the index of the hour-circle to twelve, and screw the quadrant of altitude upon the brass meridian over the given latitude; turn the globe westward on its axis till the sun's place comes to the western edge of the horizon, and the hours passed over by the index will show the time of the sun's setting, or the beginning of evening twilight; continue the motion of the globe westward till the sun's place coincides with 11° on the quadrant of altitude below the horizon, the time passed over by the index of the hour-circle, from the time of the sun's setting, will show the duration of evening twilight.

### Or, by the analemma.

Elevate the pole to the latitude of the place, as above, and screw the quadrant of altitude upon the brass meridian over the degree of latitude; bring the middle of the analemma to the brass meridian, and set the index of the hour-circle to twelve; turn the globe westward till the given day of the month, on the analemma, comes to the western edge of the horizon, and the hours passed over by the index will show the time of the sun's setting, or the beginning of evening twilight: continue the motion of the globe westward till the given day of the month coincides with 18° on the quadrant below the horizon, the time passed over by the index, from the time of the sun's setting, will show the duration of evening twilight.

Examples. 1. Required the beginning, end, and duration of morning and evening twilight at London, on the 19th of April.

*Answer.* The sun sets at two minutes past seven, and evening twilight ends at nineteen minutes past nine; consequently morning twilight begins at (12 h.—9 h. 19 m.=) 2 h. 41 m. and ends at (12 h.—7 h. 2 m.=) 4 h. 58 m.; the duration of twilight is 2 h. and 17 minutes.

2. What is the duration of twilight at London on the 23d of September? what time does dark night begin, and at what time does the day-break in the morning?

*Answer.* The sun sets at six o'clock, and the duration of twilight is two hours; consequently the evening twilight ends at eight o'clock, and the morning twilight begins at four.

3. Required the beginning, end, and duration of morning and evening twilight at London on the 25th of August.

4. Required the beginning, end, and duration of morning and evening twilight at Edinburgh on the 20th of February.

5. Required the beginning, end, and duration of morning and evening twilight at Cape Horn on the 20th of February.

6. Required the beginning, end, and duration of morning and evening twilight at Madras on the 15th of June.

## PROBLEM XXXVI.

*To find the beginning, end, and duration of constant day or twilight at any place.*

Rule. Find the latitude of the given place, and add 18° to that latitude; count the number of degrees correspondent to the sum, on that part of the brass meridian which is numbered from the pole towards the equator, mark where the reckoning ends, and observe what two points of the ecliptic pass under the mark;* that point wherein the sun's declination is increasing will show on the horizon the beginning of constant twilight; and that point wherein the sun's declination is decreasing, will show the end of constant twilight.

Examples. 1. When do we begin to have constant day or twilight at London, and how long does it continue?

*Answer.* The latitude of London is 51½ degrees north, to which add 18 degrees, the sum is 69½, the two points of the ecliptic which pass under 69½ are two degrees in ♊, answering to the 22d of May, and 29 degrees in ♋, answering to the 21st of July; so that, from the 22d of May to the 21st of July the sun never descends 18 degrees below the horizon of London.

2. When do the inhabitants of the Shetland Islands cease to have constant day or twilight?

3. Can twilight ever continue from sun-set to sun-rise at Madrid?

4. When does constant day or twilight begin at Spitzbergen?

5. What is the duration of constant day or twilight at the North Cape in Lapland, and on what day, after their long winter's night, do the sun's rays first enter the atmosphere?

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* If, after 18 degrees be added to the latitude, the distance from the pole will not reach the ecliptic, there will be no constant twilight at the given place, viz. to the given latitude add 18 degrees, and subtract the sum from 90, if the remainder exceed 23½ degrees, there can be no constant twilight at the given place.

## PROBLEM XXXVII.

### *To find the duration of twilight at the north pole.*

**Rule.** Elevate the north pole so that the equator may coincide with the horizon; observe what point of the ecliptic nearest to Libra passes under 18° below the horizon, reckoned on the brass meridian, and find the day of the month correspondent thereto; the time elapsed from the 23d of September to this time will be the duration of evening twilight. Secondly, observe what point of the ecliptic, nearest to Aries, passes under 18° below the horizon, reckoned on the brass meridian, and find the day of the month correspondent thereto; the time elapsed from that day to the 21st of March will be the duration of morning twilight.

**Examples.** 1. What is the duration of twilight at the north pole, and what is the duration of dark night there?

*Answer.* The point of the ecliptic nearest to Libra which passes under 18 degrees below the horizon, is 22 degrees in ♏, answering to the 13th of November; hence the evening twilight continues from the 23d of September (the end of the longest day) to the 13th of November the beginning of dark night) being 51 days. The point of the ecliptic nearest to Aries which passes under 18 degrees below the horizon is 9 degrees in ♒, answering to the 29th of January; hence the morning twilight continues from the 29th of January to the 21st of March (the beginning of the longest day) being 51 days. From the 23d of September to the 21st of March are 179 days, from which deduct 102 (=51 × 2), the remainder is 77 days, the duration of total darkness at the north pole; but, even during this short period, the moon and the Aurora Borealis shine with uncommon splendour.

## PROBLEM XXXVIII.

### *To find in what climate any given place on the globe is situated.*

**Rule.** 1. If the place be not in the frigid zone, find the length of the longest day at that place (by Problem XXVIII.) and subtract twelve hours therefrom; the number of half hours in the remainder will show the climate.

2. If the place be in the frigid zone,* find the length of the longest day at that place (by Problem XXX.), and if that be less than thirty days, the place is in the twenty-fifth climate, or the *first* within the polar circle. If more than thirty and less than sixty it is in the twenty-sixth climate, or the *second* within the polar circle; if more than sixty, and less than ninety, it is in the twenty-seventh climate, or the *third* within the polar circle, &c.

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* The climates between the polar circles and the poles were unknown to the ancient geographers; they reckoned only seven climates north of the equator. The middle of the first northern climate they made to pass through *Meroe*, a

**Examples.** 1. In what climate is London, and what other remarkable places are situated in the same climate?

*Answer.* The longest day in London is 16½ hours; if we deduct 12 therefrom, the remainder will be 4½ hours, or nine half hours; hence London is in the ninth climate north of the equator; and as all places in or near the same latitude are in the same climate, we shall find Amsterdam, Dresden, Warsaw, Irkoutsk, the southern part of the peninsula of Kamtschatka, Nootka Sound, the South of Hudson's Bay, the north of Newfoundland, &c. to be in the same climate as London. The learner is requested to turn to the note to Definition 69th, page 38.

2. In what climate is the North Cape in the island of Maggeroe, latitude 71° 30′ north?

*Answer.* The length of the longest day is 77 days; these days divided by 30 give two months for the quotient, and a remainder of 17 days; hence the place is in the *third* climate within the polar circle, or the 27th climate reckoning from the equator. The southern part of Nova Zembla, the northern part of Siberia, James' Island, Baffin's Bay, the northern part of Greenland, &c. are in the same climate.

3. In what climate is Edinburgh, and what other places are situated in the same climate?

4. In what climate is the north of Spitzbergen?

5. In what climate is Cape Horn?

6. In what climate is Botany Bay, and what other places are situated in the same climate?

## PROBLEM XXXIX.

*To find the breadths of the several climates between the equator and the polar circles.*

**Rule.** For the northern climates. Elevate the north pole $23\frac{1}{2}°$ above the northern point of the horizon; bring the sign Cancer to

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city of Ethiopia, built by Cambyses on an island in the Nile, nearly under the tropic of Cancer; the second through *Syene*, a city of Thebais, in Upper Egypt, near the cataracts of the Nile; the third through *Alexandria;* the fourth through *Rhodes;* the fifth through *Rome* or the *Hellespont;* the sixth through the mouth of the *Borysthenes* or *Dnieper;* and the seventh through the *Riphæan mountains*, supposed to be situated near the source of the Tanais or Don river. The southern parts of the earth being in a great measure unknown, the climates received their names from the northern ones, and not from particular towns or places. Thus the climate, which was supposed to be at the same distance from the equator southward as Meroe was northward, was called *Anti-diameroes*, or the opposite climate to Meroe; *Antidiasyenes* was the opposite climate to Syenes, &c.

the meridian, and set the index to twelve; turn the globe eastward on its axis till the index has passed over a quarter of an hour; observe that particular point of the meridian passing through Libra, which is cut by the horizon, and at the point of intersection make a mark with a pencil; continue the motion of the globe eastward till the index has passed over another quarter of an hour, and make a second mark; proceed thus till the meridian passing through Libra* will no longer cut the horizon; the several marks brought to the brass meridian will point out the latitude where each climate ends.†

**Examples.** 1. What is the breadth of the ninth north climate, and what places are situated within it?

*Answer.* The breadth of the 9th climate is 2° 57′; it begins in latitude 49° 2′ north, and ends in latitude 51° 59′ north, and all places situated within this space are in the same climate. The places will be nearly the same as those enumerated in the first example to the preceding problem.

2. What is the breadth of the second climate, and in what latitude does it begin and end?

3. Required the beginning, end, and breadth of the fifth climate.

4. What is the breadth of the seventh climate north of the equator, in what latitude does it begin and end, and what places are situated within it?

5. What is the breadth of the climate in which Petersburg is situated?

6. What is the breadth of the climate in which Mount Heckla is situated?

## PROBLEM XL.

### *To find that part of the equation of time which depends on the obliquity of the ecliptic.*

**Rule.** Find the sun's place in the ecliptic, and bring it to the brass meridian; count the number of degrees from Aries to the brass meridian, on the equator and on the ecliptic; the difference, reckoning four minutes of time to a degree, is the equation of time. If the number of degrees on the ecliptic exceed those on the equator, the sun is faster than the clock; but if the number of degrees on the equator exceed those on the ecliptic, the sun is slower than the clock.

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* On Adams' and Cary's globes, the meridian passing through Libra is divided into degrees, in the same manner as the brass meridian is divided; the horizon will, therefore, cut this meridian in the several degrees answering to the end of each climate, without the trouble of bringing it to the brass meridian, or marking the globe.

† See a Table of the climates, with the method of constructing it, at pages 39 and 40.

*Note.* The equation of time, or difference between the time shown by a well regulated clock, and a true sun-dial, depends upon two causes, viz. the obliquity of the ecliptic, and the unequal motion of the earth in its orbit. The former of these causes may be explained by the above Problem. If two suns were to set off at the same time from the point Aries, and move over equal spaces in equal time, the one on the ecliptic, the other on the equator, it is evident they would never come to the meridian together, except at the time of the equinoxes, and on the longest and shortest days. The annexed table shows how much the sun is faster or slower than the clock ought to be, so far as the variation depends on the obliquity of the ecliptic only. The signs of the first and third quadrants of the ecliptic are at the top of the table, and the degrees in these signs on the left hand; in any of these signs the sun is faster than the clock. The signs of the second and third quadrants are at the bottom of the table, and the degrees in these signs at the right hand; in any of these signs the sun is slower than the clock.

Thus, when the sun is in 20 degrees of ♉ or ♏, it is 9 minutes 50 seconds faster than the clock, and, when the sun is in 18 degrees of ♋ or ♑, it is 6 minutes 2 seconds slower than the clock.

SUN *faster than the* CLOCK *in*

| Degrees. | ♈<br>♎ | | ♉<br>♏ | | ♊<br>♐ | | 1 Qu<br>3 Qu |
|---|---|---|---|---|---|---|---|
| | M. | S. | M. | S. | M. | S. | |
| 0 | 0 | 0 | 8 | 24 | 8 | 46 | 30 |
| 1 | 0 | 20 | 8 | 35 | 8 | 36 | 29 |
| 2 | 0 | 40 | 8 | 45 | 8 | 25 | 28 |
| 3 | 1 | 0 | 8 | 54 | 8 | 14 | 27 |
| 4 | 1 | 19 | 9 | 3 | 8 | 1 | 26 |
| 5 | 1 | 39 | 9 | 11 | 7 | 49 | 25 |
| 6 | 1 | 59 | 9 | 18 | 7 | 35 | 24 |
| 7 | 2 | 18 | 9 | 24 | 7 | 21 | 23 |
| 8 | 2 | 37 | 9 | 31 | 7 | 6 | 22 |
| 9 | 2 | 56 | 9 | 36 | 6 | 51 | 21 |
| 10 | 3 | 16 | 9 | 41 | 6 | 35 | 20 |
| 11 | 3 | 34 | 9 | 45 | 6 | 19 | 19 |
| 12 | 3 | 53 | 9 | 49 | 6 | 2 | 18 |
| 13 | 4 | 11 | 9 | 51 | 5 | 45 | 17 |
| 14 | 4 | 29 | 9 | 53 | 5 | 27 | 16 |
| 15 | 4 | 47 | 9 | 54 | 5 | 9 | 15 |
| 16 | 5 | 4 | 9 | 55 | 4 | 50 | 14 |
| 17 | 5 | 21 | 9 | 55 | 4 | 31 | 13 |
| 18 | 5 | 38 | 9 | 54 | 4 | 12 | 12 |
| 19 | 5 | 54 | 9 | 52 | 3 | 52 | 11 |
| 20 | 6 | 10 | 9 | 50 | 3 | 32 | 10 |
| 21 | 6 | 26 | 9 | 47 | 3 | 12 | 9 |
| 22 | 6 | 41 | 9 | 43 | 2 | 51 | 8 |
| 23 | 6 | 35 | 9 | 38 | 2 | 30 | 7 |
| 24 | 7 | 9 | 9 | 33 | 2 | 9 | 6 |
| 25 | 7 | 23 | 9 | 27 | 1 | 48 | 5 |
| 26 | 7 | 36 | 9 | 20 | 1 | 27 | 4 |
| 27 | 7 | 49 | 9 | 13 | 1 | 5 | 3 |
| 28 | 8 | 1 | 9 | 5 | 0 | 43 | 2 |
| 29 | 8 | 13 | 8 | 56 | 0 | 22 | 1 |
| 30 | 8 | 24 | 8 | 46 | 0 | 0 | 0 |
| 2 Qu<br>4 Qu | ♍<br>♓ | | ♌<br>♒ | | ♋<br>♑ | | Deg. |

*Sun slower than the* CLOCK *in*

**Examples.** 1. What is the equation of time on the 17th of July?

*Answer.* The degrees on the equator exceed the degrees on the ecliptic by two: hence the sun is eight minutes slower than the clock.*

2. On what four days of the year is the equation of time nothing?

3. What is the equation of time dependant on the obliquity of the ecliptic on the 27th of October?

4. When the sun is in 18° of Aries, what is the equation of time?

## PROBLEM XLI.

### *To find the sun's meridian altitude at any time of the year at any given place.*

**Rule.** Find the sun's declination, and elevate the pole to that declination; bring the given place to the brass meridian, and count the number of degrees on the brass meridian (the nearest way) to the horizon; these degrees will show the sun's meridian altitude.†

**Note.** *The sun's altitude may be found at any particular hour, in the following manner.*

Find the sun's declination, and elevate the pole to that declination; bring the given place to the brass meridian and set the index to 12; then, if the given time be before noon, turn the globe westward as many hours as the time wants of noon; if the time be past noon, turn the globe eastward as many hours as the time is past noon. Keep the globe fixed in this position, and screw the quadrant of altitude on the brass meridian over the sun's declination; bring the graduated edge of the quadrant to coincide with the given place, and the number of degrees between that place and the horizon will show the sun's altitude.

### Or,

Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the sun's place in the ecliptic, and bring it to that part of the brass meridian which is numbered from the equator towards the poles; count the number of degrees contained on the brass meridian between the sun's place and the horizon, and they will show the altitude.*

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* The learner will observe that the equation of time here determined is not the true equation, as noted on the 7th circle on the horizon of Bardin's globes; the equation of time there given cannot be determined by the globe. See the table at the end of Problem LXIV.

† See Problem XXI.

To find the sun's *altitude* at any hour, see Problem XLIV.

### OR, BY THE ANALEMMA.

Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the day of the month on the analemma, and bring it to that part of the brass meridian which is numbered from the equator towards the poles; count the number of degrees contained on the brass meridian between the given day of the month and the horizon, and they will show the altitude.

To find the sun's *altitude* at any hour, see Problem XLIV.

EXAMPLES. 1. What is the sun's meridian altitude at London on the 21st of June?

*Answer.* 62 degrees.

2. What is the sun's meridian altitude at London on the 21st of March?

3. What is the sun's least meridian altitude at London?

4. What is the sun's greatest meridian altitude at Cape Horn?

5. What is the sun's meridian altitude at Madras on the 20th of June?

6. What is the sun's meridian altitude at Bencoolen on the 15th of January?

### EXAMPLES *to the note.*

1. What is the sun's altitude at Madrid on the 24th of August, at 11 o'clock in the morning?†

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* See Problem XXII.

† This example is taken from a prospectus, announcing the publication of *New Globes*, to be executed by Mr. Dudley Adams, and called the *Newtonian Globes*, wherein the author has treated the *common* globes with *uncommon* severity; he has, however, been rather unfortunate in the choice of his examples, which are designed to show "the *absurdities* and *ridiculous inconsistencies* of the common globes." He says, "By working *this* problem on the common globes, we find, with the greatest astonishment, that Madrid, where it is understood to be eleven o'clock in the morning, is at that time in the dark, under the horizon; and consequently we hardly conceive how the inhabitants can see the sun to take its altitude, and calculate the time to be eleven o'clock."—*Ex uno disce omnes.*

*Answer.* The sun's declination is 11¼ degrees north; by elevating the north pole 11¼ degrees above the horizon, and turning the globe so that Madrid may be *one* hour westward of the meridian, the sun's altitude will be found to be 57¼ degrees.

2. What is the sun's altitude at London at 3 o'clock in the afternoon on the 25th of April?

3. What is the sun's altitude at Rome on the 16th of January at 10 o'clock in the morning?

4. Required the sun's altitude at Buenos Ayres on the 21st of December at two o'clock in the afternoon.

## PROBLEM XLII.

*When it is midnight at any place in the temperate or torrid zones, to find the sun's altitude at any place (on the same meridian) in the north frigid zone, where the sun does not descend below the horizon.*

Rule. Find the sun's declination for the given day, and elevate the pole to that declination; bring the place (in the frigid zone) to that part of the brass meridian which is numbered from the north pole towards the equator, and the number of degrees between it and the horizon will be the sun's altitude.

Or,

Elevate the north pole so many degrees above the horizon as are equal to the latitude of the place in the frigid zone; bring the sun's place in the ecliptic to the brass meridian, and set the index of the hour-circle to twelve; turn the globe on its axis till the index points to the other twelve; and the number of degrees between the sun's place and the horizon, counted on the brass meridian towards that part of the horizon marked north, will be the sun's altitude.

Examples. 1. What is the sun's altitude at the North Cape in Lapland, when it is midnight at Alexandria in Egypt on the 21st of June?

*Answer.* 5 degrees.

2. When it is midnight to the inhabitants of the island of Sicily on the 22d of May, what is the sun's altitude at the north of Spitzbergen, in latitude 80° north?

3. What is the sun's altitude at the north-east of Nova Zembla, when it is midnight at Tobolsk, on the 15th of July?

4. What is the sun's altitude at the north of Baffin's Bay, when it is midnight at Buenos Ayres, on the 28th of May?

## PROBLEM XLIII.

### *To find the sun's amplitude at any place, the day of the month being given.*

Elevate the pole so many degrees above the horizon as are equal to the latitude of the given place; find the sun's place in the ecliptic, and bring it to the eastern semi-circle of the horizon; the number of degrees from the sun's place to the east point of the horizon will be the rising amplitude; bring the sun's place to the western semi-circle of the horizon, and the number of degrees from the sun's place to the west point of the horizon will be the setting amplitude.

### OR, BY THE ANALEMMA.

Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; bring the day of the month on the analemma to the eastern semi-circle of the horizon; the number of degrees from the day of the month to the east point of the horizon will be the rising amplitude: bring the day of the month to the western semi-circle of the horizon, and the number of degrees from the day of the month to the west point of the horizon will be the setting amplitude.

EXAMPLES. 1. What is the sun's amplitude at London on the 21st of June?

*Answer.* 39° 48′ to the north of the east, and 39° 48′ to the north of the west.

2. On what point of the compass does the sun rise and set at London on the 17th of May?

3. On what point of the compass does the sun rise and set at the Cape of Good Hope on the 21st of December?

4. On what point of the compass does the sun rise and set on the 21st of March?

5. On what point of the compass does the sun rise and set at Washington on the 21st of October?

6. On what point of the compass does the sun rise and set at Petersburg on the 18th of December?

7. On December 22d, 1825, in latitude 31° 38′ S., and longi-

tude 83° W., if the sun set on the S.W. point of the compass, what is the variation?

8. On the 15th of May, 1825, if the sun rise E. by N. in latitude 33° 15′ N. and longitude 18° W., what is the variation of the compass?

## PROBLEM XLIV.

*To find the sun's azimuth and his altitude at any place, the day and hour being given.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian, over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve; then if the given time be before noon, turn the globe eastward* as many hours as it wants of noon; but, if the given time be past noon, turn the globe westward as many hours as it is past noon; bring the graduated edge of the quadrant of altitude to coincide with the sun's place, then the number of degrees on the horizon, reckoned from the north or south point thereof to the graduated edge of the quadrant, will show the azimuth; and the number of degrees on the quadrant counting from the horizon to the sun's place, will be the sun's altitude.

### Or, by the analemma.

Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian, over that latitude; bring the middle of the analemma to the brass meridian, and set the index of the hour-circle to twelve; then, if the given time be before noon, turn the globe eastward on its axis as many hours as it wants of noon; but, if the given time be past noon, turn the globe westward as many hours as it is past noon; bring the graduated edge of the quadrant of altitude to coincide with the day of the month on the analemma, then the number of degrees on the horizon, reckoned from the north or south point thereof to the graduated edge of the quadrant, will show the azimuth; and the number of degrees on the quadrant, counting from the horizon to the day of the month, will be the sun's altitude.

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* Whenever the pole is elevated for the latitude of the place, the proper motion of the globe is from *east to west*, and the *sun* is on the east side of the brass meridian in the morning, and on the west side in the afternoon; but when the pole is elevated for the sun's declination, the motion is from *west to east*, and the *place* is on the west side of the meridian in the morning, and on the east side in the afternoon.

EXAMPLES. 1. What is the sun's altitude, and his azimuth from the north, at London, on the first of May, at ten o'clock in the morning?

*Answer.* The altitude is 47°, and the azimuth from the north 136°, or from the south 44°.

2. What is the sun's altitude and azimuth at Petersburg on the 13th of August, at half-past five o'clock in the morning?

3. What is the sun's azimuth and altitude at Antigua, on the 21st of June, at half-past six in the morning, and at half-past ten?*

4. At Barbadoes, on the 21st of June, required the sun's azimuth and altitude at 8 minutes past 6, and at ¾ past nine in the morning: also at ¼ past 2, and at 52 minutes past 5 in the afternoon.

5. On the 13th of August, at half-past eight o'clock in the morning, at sea in latitude 57° N. the observed azimuth of the sun was S. 49° 14' E., what was the sun's altitude, his true azimuth, and the variation of the compass?

6. On the 14th of January, in latitude 33° 52' S., at half-past three o'clock in the afternoon, the sun's magnetic azimuth was observed to be N. 63° 51' W., what was the true azimuth, the variation of the compass, and the sun's altitude?

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* In all places in the torrid zone, whenever the declination of the sun exceeds the latitude of the place, and both are of the same name, the sun will appear twice in the forenoon and twice in the afternoon, on the same point of the compass, and will cause the shadow of an azimuth dial to go back several degrees. In this example, the sun's azimuth at the hours given above, will be 69° from the north towards the east; and at half-past eight o'clock, the sun will appear to have the same azimuth [illegible]

## PROBLEM XLV.

*The latitude of the place, day of the month, and the sun's altitude being given, to find the sun's azimuth and the hour of the day.*[*]

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian, over that latitude; bring the sun's place in the ecliptic to the brass meridian, and set the index of the hour circle to twelve; turn the globe on its axis till the sun's place in the ecliptic coincides with the given degree of altitude on the quadrant; the hours passed over by the index of the hour circle will show the time from noon, and the azimuth will be found on the horizon, as in the preceding problem.

### Or, by the analemma.

Elevate the pole to the latitude of the place, and screw the quadrant of altitude over that latitude; bring the middle of the analemma to the brass meridian, and set the index of the hour circle to twelve; move the globe and quadrant till the day of the month coincides with the given altitude, the hours passed over by the index will show the time from noon, and the azimuth will be found in the horizon as before.

Examples. I. At what hour of the day on the 21st of March is the sun's altitude 22¼° at London, and what is his azimuth? The observation being made in the afternoon.

*Answer.* The time from noon will be found to be 3 hours 30 minutes, and the azimuth 59° 1′ from the south towards the west. Had the observations been made before noon, the time from noon would have been 3 1-2 hours, viz. it would have been 30 minutes past eight in the morning, and the azimuth would have been 59° 1′ from the south towards the east.[†]

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[*] This problem is only a variation of the preceding; for, by the nature of spherical trigonometry, any three of the following quantities, viz. the *latitude* of the place, the *sun's declination*, *altitude*, *azimuth*, or *time of the day*, being given, the rest may be found, admitting of several variations. A large collection of Astronomical problems may be found in *Keith's Trigonometry*, fourth edition, page 281, &c. These problems are useful exercises on the globes.

[†] The learner will observe, that the sun has the same altitude at equal distances from noon; hence it is necessary to say whether the observation be made before or after noon, otherwise the problem admits of two answers.

2. At what hour on the [illegible] of March is the sun's altitude 25° at London, and what is his azimuth? The observation being made in the forenoon.

3. At what hour on the 19th of May is the sun's altitude 30° at Lisbon, and what is the azimuth? The observation being made in the afternoon.

4. Walking along the side of Queen-square in London, on the 5th of August in the forenoon, I observed the shadows of the iron rails to be exactly the same length as the rails themselves; pray what o'clock was it, and on what point of the compass did the shadows of the rails fall?

5. In latitude 13° 30′ N., on the 21st of June, the sun had the same azimuth at two *different* times in the morning; and also in the afternoon, viz. when his altitude was 7° 17′ and 58° 55′: required the azimuth and the hours of the day. It is likewise required to find the azimuth when it is the greatest, and the hour; the altitude at that time being 35° 50′.

## PROBLEM XLVI.

*Given the latitude of the place, and the day of the month, to find at what hour the sun is due east or west.*

**Rule.** Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve; screw the quadrant of altitude on the brass meridian, over the given latitude, and move the lower end of it to the east point of the horizon; hold the quadrant in this position, and move the globe on its axis, till the sun's place comes to the graduated edge of the quadrant; the hours passed over by the index from twelve will be the time from noon when the sun is due east,* and at the same time from noon he will be due west.

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* If the latitude be north, and the sun's declination be south, he will be due east and west when he is below the horizon; and the same thing will happen if the latitude be south when the declination is north. Examples exercising these cases are useless; however they are easily solved, if we consider that, when the sun is due east below the horizon at any time, the opposite point of the ecliptic will be due west above the horizon; therefore, instead of bringing the lower edge of the quadrant to the east of the horizon, bring it to the west, and, instead of using the sun's place, make use of a point in the ecliptic diametrically opposite.

### OR, BY THE ANALEMMA.

This is exactly the same as above, only, instead of bringing the sun's place to the meridian, you bring the analemma there, and, instead of bringing the sun's place to the graduated edge of the quadrant, the day of the month on the analemma must be brought to it.

**EXAMPLES.** 1. At what hour will the sun be due east at London on the 19th of May; at what hour will he be due west; and what will his altitude be at these times?

*Answer.* The time from 12, when the sun is due east, is 4 hours 54 minutes; hence the sun is due east at six minutes past seven o'clock in the morning, and due west at 54 minutes past four in the afternoon; the sun's altitude will be found at the same time, as in Problem XLIV. In this example it is 25° 26′.

2. At what hours will the sun be due east and west at London on the 21st of June, and on the 21st of December; and what will be his altitude above the horizon on the 21st of June?

3. Find at what hours the sun will be due east and west, not only at London but at every place on the surface of the globe, on the 21st of March and on the 23d of September.

4. At what hours is the sun due east and west at Buenos Ayres on the 21st of December?

## PROBLEM XLVII.

*Given the sun's meridian altitude, and the day of the month, to find the latitude of the place.*

**RULE.** Find the sun's place in the ecliptic, and bring it to that part of the brass meridian which is numbered from the equator towards the poles; then, if the sun was south* of the observer when the altitude was taken, count the number of degrees from the sun's place on the brass meridian towards the south point of the horizon, and mark where the reckoning ends; bring this mark to coincide with the south point of the horizon, and the elevation of the north pole will show the latitude. If the sun was north of the observer when the altitude was taken, the degrees must be counted in a similar manner, from the sun's place towards the north point of the horizon, and the elevation of the south pole will show the latitude.

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* It is necessary to state whether the sun be to the north or south of the observer at noon, otherwise the problem is unlimited.

### OR, WITHOUT A GLOBE.

Subtract the sun's altitude from ninety degrees, the remainder is the zenith distance. If the sun be south when the altitude is taken, call the zenith distance north; but, if north, call it south; find the sun's declination in an ephemeris* or a table of the sun's declination, and mark whether it be north or south; then, if the zenith distance and declination have the same name, their sum is the latitude, but, if they have contrary names, their difference is the latitude, and it is always of the same name with the greater of the two quantities.

EXAMPLES. 1. On the 10th of May, 1825, I observed the sun's meridian altitude to be 50°, and it was south of me at that time; required the latitude of the place.

*Answer.* 57° 37′ north.

*By calculation.*

90° 0′
50 0 S., sun's altitude at noon.

40 0 N., the zenith's distance.
17 37 N., the sun's declination 10th May, 1825.

57 37 N., the latitude sought.

2. On the 10th of May, 1825, the sun's meridian altitude was observed to be 50°, and it was north of the observer at that time; required the latitude of the place.

*Answer.* 22° 23′ south.

*By calculation.*

90° 0′
50 0 N., sun's altitude at noon.

40 0 S., the zenith's distance.
17 37 N., the sun's declination 10th of May, 1825.

22 23 S., the latitude sought.

3. On the 5th of August 1825, the sun's meridian altitude was observed to be 74° 30′ north of the observer; what was the latitude?

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* The most convenient is the Nautical Almanac, or White's Ephemeris; see the note page 57.

4. On the 19th of November, 1825, the sun's meridian altitude was observed to be 40° south of the observer; what was the latitude?

5. At a certain place, where the clocks are two hours faster than at London, the sun's meridian altitude was observed to be 30 degrees to the south of the observer on the 21st of March; required the place.

6. At a place where the clocks are five hours slower than at London, the sun's meridian altitude was observed to be 60° to the south of the observer on the 16th of April, 1825; required the place.

## PROBLEM XLVIII.

### *The length of the longest day at any place, not within the polar circles, being given, to find the latitude of that place.*

**Rule.** Bring the first point of Cancer or Capricorn to the brass meridian (according as the place is on the north or south side of the equator), and set the index of the hour circle to twelve; turn the globe westward on its axis till the index of the hour circle has passed over as many hours as are equal to half the length of the day; elevate or depress the pole till the sun's place (viz. Cancer or Capricorn) comes to the horizon; then the elevation of the pole will show the latitude.

Note. This problem will answer for any day in the year, as well as the longest day, by bringing the sun's place to the brass meridian and proceeding as above.

Or, bring the middle of the analemma to the brass meridian, and set the index of the hour circle to 12; turn the globe westward on its axis till the index has passed over as many hours as are equal to half the length of the day; elevate or depress the pole till the day of the month coincides with the horizon, then the elevation of the pole will show the latitude.

**Examples.** 1. In what degree of north latitude, and at what places is the length of the longest day 16½ hours?

*Answer.* In latitude 52°, and all places situated on, or near that parallel of latitude, have the same length of day.

2. In what degree of south latitude, and at what places is the longest day 14 hours?

3. In what degree of north latitude is the length of the longest day three times the length of the shortest night?

4. There is a town in Norway where the longest day is five times the length of the shortest night; pray what is the name of the town?

5. In what latitude north does the sun set at seven o'clock on the 5th of April?
6. In what latitude south does the sun rise at five o'clock on the 25th of November?
7. In what latitude north is the 20th of May 16 hours long?
8. In what latitude north is the night of the 15th of August 10 hours long?

## PROBLEM XLIX.

*The latitude of a place and the day of the month being given, to find how much the sun's declination must vary to make the day an hour longer or shorter than the given day.*

Rule. Find the sun's declination for the given day, and *elevate* the pole to that declination; bring the given place to the brass meredian, and set the index of the hour circle to twelve; turn the globe eastward on its axis till the given place comes to the horizon, and observe the hours passed over by the index. Then, if the days be increasing, continue the motion of the globe eastward till the index has passed over an other half-hour, and raise or depress the pole till the place comes again into the horizon, the elevation of the pole will show the sun's declination when the day is an hour longer than the given day; but, if the days be decreasing, after the place is brought to the eastern part of the horizon, turn the globe westward till the index has passed over half-an-hour, then raise or depress the pole till the place comes a second time into the horizon, the last elevation of the pole will show the sun's declination when the day is an hour shorter than the given day.

Or,

Elevate the pole to the latitude of the place, find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve: turn the globe westward on its axis till the sun's place comes to the horizon, and observe the hours passed over by the index; then, if the days be increasing, continue the motion of the globe westward till the index has passed over an other half-hour, and observe what point of the ecliptic is cut by the horizon; that point will show the sun's place when the day is an hour longer than the given day, whence the declination is readily found; but, if the days be decreasing, turn the globe eastward till the index has passed over half-an-hour, and observe what point of the ecliptic is cut by the horizon; that point will show the sun's place when the day is an hour shorter than the given day.

### OR, BY THE ANALEMMA.

Proceed exactly the same as above, only, instead of bringing the sun's place to the brass meridian, bring the analemma there, and instead of the sun's place, use the day of the month on the analemma.

EXAMPLES. 1. How much must the sun's declination vary that the day at London may be increased one hour from the 24th of February?

*Answer.* On the 24th of February the sun's declination is 9° 38′ south, and the sun sets at a quarter past five; when the sun sets at three quarters past five, his declination will be found to be about 4¼ south answering to the tenth of March: hence the declination has decreased 5° 23′, and the days have increased 1 hour in 14 days.

2. How much must the sun's declination vary that the day at London may decrease *one* hour in length from the 26th of July?

*Answer.* The sun's declination on the 26th of July is 19° 38′ north, and the sun sets at 49 min. past seven; when the sun sets at 19 minutes past seven, his declination will be found to be 14° 43′ north, answering to the 13th of August: hence the declination has decreased 5° 55′, and the days have decreased *one* hour in 18 days.

3. How much must the sun's declination vary from the 5th of April, that the day at Petersburg may increase *one* hour?

4. How much must the sun's declination vary, from the 4th of October, that the day at Stockholm may decrease *one* hour?

5. What is the difference in the sun's declination, when he rises at seven o'clock at Petersburg, and when he sets at nine?

## PROBLEM L.

*To find the sun's right ascension, oblique ascension, oblique descension, ascensional difference, and time of rising and setting at any given place, the day of the month being given.*

RULE. Find the sun's place in the ecliptic, and bring it to that part of the brass meridian which is numbered from the equator towards the poles;* the degree on the equator cut by the

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* The degree on the meridian above the sun's place is the sun's declination. See Problem XX.

**graduated edge of the brass meridian, reckoning from the point Aries eastward, will be the sun's right ascension.**

**Elevate the poles so many degrees above the horizon as are equal to the latitude of the place, bring the sun's place in the ecliptic to the eastern part of the horizon,* and the degree on the equator cut by the horizon, reckoning from the point Aries eastward, will be the sun's oblique ascension. Bring the sun's place in the ecliptic to the western part of the horizon,† and the degree on the equator cut by the horizon, reckoning from the point Aries eastward, will be the sun's oblique descension.**

**Find the difference between the sun's right and oblique ascension, or, which is the same thing, the difference between the right ascension and oblique descension, and turn this difference into time by multiplying by four,‡ then, if the sun's declination and the latitude of the place be both of the same name, viz. both north or both south, the sun rises before six and sets after six, by a space of time equal to the ascensional difference; but if the sun's declination and the latitude be of contrary names, viz. the one north and the other south, the sun rises after six and sets before six.**

**Examples.** 1. Required the sun's right ascension, oblique ascension, oblique descension, ascensional difference, and time of rising and setting at London, on the 15th of April?

*Answer.* The right ascension is 23° 30′, the oblique ascension is 9° 45′, the ascensional difference (23° 30′— 9° 45′ =) 13° 45′, or 55 minutes of time; consequently the sun rises 55 minutes before six, or 5 minutes past 5, and sets 55 minutes past 6. The oblique descension is 37° 15′; consequently the descensional difference is (37° 15′—23° 30′=) 13° 45′ the same as the ascensional difference.

2. What are the sun's right ascension, oblique ascension, and oblique descension, on the 27th of October at London; what is the ascensional difference, and at what time does the sun rise and set?

3. What are the sun's right ascension, declination, oblique ascension, rising amplitude, oblique descension, and setting amplitude at London, on the 1st of May; what is the ascensional difference, and at what time does the sun rise and set?

4. What are the sun's right ascension, declination, oblique ascension, rising amplitude, oblique descension, and setting ampli-

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* The rising amplitude may be seen at the same time. See Problem XLIII.

† The setting amplitude may here be seen. Vide Problem XLIII.

‡ See Problem XVIII.

tude at Petersburg, on the 21st of June; what is the ascensional difference, and at what time does the sun rise and set?

5. What are the sun's right ascension, declination, oblique ascension, rising amplitude, oblique descension, and setting amplitude, at Alexandria, on the 21st of December: what is the ascensional difference, and at what time does the sun rise and set?

## PROBLEM LI.

*Given the day of the month and the sun's amplitude, to find the latitude of the place of observation.*

Rule. Find the sun's place in the ecliptic, and bring it to the eastern or western part of the horizon (according as the eastern or western amplitude is given); elevate or depress the pole till the sun's place coincides with the given amplitude on the horizon, then the elevation of the pole will show the latitude.

Or, thus:

Elevate the north pole to the complement[*] of the amplitude, and screw the quadrant of altitude upon the brass meridian over the same degree: bring the equinoctial point Aries to the brass meridian, and move the quadrant of altitude till the sun's declination for the given day (counted on the quadrant) coincides with the equator; the number of degrees between the point Aries and the graduated edge of the quadrant will be the latitude sought.

Examples. 1. The sun's amplitude was observed to be 39° 48′ from the east towards the north, on the 21st of June; required the latitude of the place?

*Answer.* 51° 32′ north.[†]

2. The sun's amplitude was observed to be 15° 30′ from the

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[*] The complement of the amplitude is found by subtracting the amplitude from 90°. This rule is exactly the same as above; for it is formed from a right-angled spherical triangle, the base being the complement of the amplitude, the perpendicular the latitude of the place; and the hypothenuse the complement of the sun's declination.

[†] See *Keith's Trigonometry*, fourth edition, page 285.

**east towards the north, at the same time his declication was 15° 30′; required the latitude.**

**3. On the 29th of may, when the sun's declination was 21° 30′ north, his rising amplitude was known to be 22° northward of the east? required the latitude.**

**4. When the sun's declination was 2° north, his rising amplitude was 4° north of the east; required the latitude.**

## PROBLEM LII.

*Given two observed altitudes of the sun, the time elapsed between them, and the sun's declination, to find the latitude.*

RULE. Find the sun's declination, either by the globe or an ephemeris; take the number of degrees contained therein from the equator with a pair of compasses, and apply the same number of degrees upon the meridian passing through Libra* from the equator northward or southward, and mark where they extend to; turn the elapsed time into degrees,† and count those degrees upon the equator from the meridian passing through Libra; bring that point of the equator where the reckoning ends to the graduated edge of the brass meridian, and set off the sun's declination from that point along the edge of the meridian, the same way as before; then take the complement of the first altitude from the equator in your compasses, and, with one foot in the sun's declination, and a fine pencil in the other foot, describe an arc; take the complement of the second altitude in a similar manner from the equator, and with one foot of the compasses fixed in the second point of the sun's declination, cross the former arc; the point of intersection brought to that part of the brass meridian which is numbered from the equator towards the poles, will stand under the degree of latitude sought.‡

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* Any meridian will answer the purpose as well as that which passes through Libra; on Adam's and on Cary's globes this meridian is divided like the brass meridian.

† See the method of turning time into degrees. Prob. XIX.

‡ The calculation of this problem by spherical trigonometry, and also the analytical calculation are given in Emerson's Algebra, pages 446, and 447, second edition. In applying the problem to Nautical Astromomy it is usual to give also the latitude by account, from which the true latitude is obtained by corrective approximation.

**Examples.** 1. Suppose on the 4th of June 1825, in north latitude, the sun's altitude at 29 minutes past 10 in the forenoon, to be 65° 24′, and 31 minutes past 12, 74° 8′: required the latitude.

*Answer.* The sun's declination is 22° 26′ north, the elapsed time two hours two minutes, answering to 30° 30′; the complement of the first altitude 24° 36′, the complement of the second altitude 15° 52′, and the latitude sought 36° 57′ north.

2. * Given the sun's declination 19° 39′ north, his altitude in the forenoon 38° 19′, and, at the end of one hour and a half, the same morning, the altitude was 50° 25′; required the latitude of the place, supposing it to be north.

3. When the sun's declination was 22° 40′ north, his altitude at 10h. 54m. in the forenoon was 53° 29′, and 1h. 17m. in the afternoon it was 52° 48′; required the latitude of the place of observation, supposing it to be north.

4. In north latitude, when the sun's declination was 22° 23′ south, the sun's altitude in the afternoon was observed to be 14° 46′, and after 1h. 22m. had elapsed, his altitude was 8° 27′; required the latitude.

## PROBLEM LIII.

*The day and hour being given when a solar eclipse will happen, to find where it will be visible.*

**Rule.** Find the sun's declination, and elevate the pole agreeably to that declination; bring the place at which the hour is given to that part of the brass meridian which is numbered from the equator towards the poles, and set the index of the hour circle to twelve; then, if the given time be before noon, turn the globe westward till the index has passed over as many hours as the given time wants of noon; if the time be past noon, turn the globe eastward as many hours as it is past noon, and exactly under the degree of the sun's declination on the brass meridian you will find the place on the globe where the sun will be vertically eclipsed*: at all places within 70 degrees of this place, the eclipse *may*† be visible, especially if it be a total eclipse.

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* A great variety of examples accurately calculated by a general rule, without an assumed latitude, may be seen in *Keith's Trigonometry*, fourth edition page 323, &c.

**Example.** On the 11th of February, 1804, at 27 min. past ten o'clock in the morning at London, there was an eclipse of the sun: where was it visible, supposing the moon's penumbral shadow to extend northward 70 degrees from the place where the sun was vertically eclipsed?

*Answer.* London, &c. For more examples consult the Table of Eclipses, following the next problem.

## PROBLEM LIV.

*The day and hour being given when a lunar eclipse will happen, to find where it will be visible.*

**Rule.** Find the sun's declination for the given day, and note whether it be north or south; if it be north, elevate the *south* pole so many degrees above the horizon as are equal to the declination; if it be south, elevate the *north* pole in a similar manner; bring the place at which the hour is given to that part of the brass meridian which is numbered from the equator towards the poles, and set the index of the hour circle to twelve; then, if the given time be before noon, turn the globe westward as many hours as it wants of noon; if after noon, turn the globe eastward as many hours as it is past noon; the place exactly under the degree of the sun's declination will be the antipodes of the place where the moon is vertically eclipsed, set the index of the hour circle again to twelve, and turn the globe on its axis till the index has passed over twelve hours: then to all places above the horizon the eclipse will be visible; to those places along the western edge of the horizon, the moon will rise eclipsed; to those along the eastern edge she will set eclipsed; and to that place immediately under *the degree* of the sun's declination, reckoned towards the elevated pole, the moon will be vertically eclipsed.

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* The effect of parallax is so great, that an eclipse may not be visible even where the sun is vertical.

† When the moon is exactly in the node, and when the axes of the moon's shadow and penumbra pass through the centre of the earth, the breadth of the earth's surface under the penumbral shadow is 70° 20′; but the breadth of this shadow is variable; and if it be not accurately determined by calculation, it is impossible to tell by the globe to what extent an eclipse of the sun will be visible.

EXAMPLE. On the 26th of January 1804, at 58 min. past seven in the afternoon at London, there was an eclipse of the moon; where was it visible?

*Answer.* It was visible to the whole of Europe, Africa, and the continent of Asia. For more examples see the following Table of Eclipses.

NOTE. The substance of the following Table of Eclipses was extracted from *Dr. Hutton's* translation of *Montucla's* edition of *Ozanam's Mathematical* and *Physical Recreations*, published by Mr. Kearsley in Fleet-street. These eclipses were originally calculated by M. Pingré, a member of the Academy of Sciences, and published in *L' Art de verifier les Dates.* In classing these tables the arrangement of Mr. Ferguson has been followed; see page 267 of his Astronomy, where a catalogue of the visible eclipses is given from 1700 to 1800, taken from *L' Art de verifier les Dates.* It may be necessary to inform the learner, that the times of these eclipses, as calculated by M. Pingré, are not perfectly accurate, and were only designed to show nearly the time when an eclipse may be expected to happen. The limits where these eclipses are visible are generally from the tropic of Cancer in Africa, to the northern extremity of Lapland, and from the 5th degree of north latitude in Asia, to the north polar circle; though some few of them are visible beyond the pole. In longitude, the limits are the fifth and 155th meridians, supposing the 20th to pass through Paris; hence it appears that they are calculated for the meridian of Ferro; which will make their limits from London to be from 12 46′ west long. to 137° 14′ east. M. Pingré says, that an eclipse of the sun is visible from 32° to 64° north, and as far south of the place where it is central. In the following table the moon is represented by ◐, the sun by ☉, T stands for total, P for partial, M for morning, and A for afternoon, the rest is obvious.

| Years. | | Months and Days. | Time. |
|---|---|---|---|
| 1826 | ◐ T | May 21 | 3½ A |
| — | ◐ T | Nov. 14 | 4½ A |
| — | ☉ | Nov. 29 | 11½ M |
| 1827 | ☉ | April 26 | 3½ M |
| — | ◐ P | May 11 | 8¾ M |
| — | ◐ P | Nov. 3 | 5 A |
| 1828 | ☉ | April 14 | 9¼ M |
| — | ☉ | Oct. 9 | 0½ M |
| 1829 | ◐ P | March 20 | 2 A |
| — | ◐ P | Sept. 13 | 7 M |
| — | ☉ | Sept. 28 | 2½ M |
| 1830 | ☉ | Feb. 23 | 5 M |
| — | ◐ T | March 9 | 2 A |
| — | ◐ T | Sept. 2 | 11 A |
| 1831 | ◐ P | Feb. 26 | 5 A |
| — | ◐ P | Aug. 23 | 10½ M |
| 1832 | ☉ | July 27 | 2½ A |
| 1833 | ◐ P | Jan. 6 | 8 M |
| — | ◐ P | July 2 | 1 M |
| — | ☉ | July 17 | 7 M |
| — | ◐ T | Dec. 26 | 10 A |
| 1834 | ◐ T | June 21 | 8½ M |
| — | ◐ P | Dec. 16 | 5¼ M |
| 1835 | ☉ | May 27 | 1½ A |
| — | ◐ P | June 10 | 11 A |
| — | ☉ | Nov. 20 | 11 M |
| 1836 | ◐ T | May 1 | 8½ M |
| — | ☉ | May 15 | 2½ A |
| — | ◐ P | Oct. 24 | 1¾ A |
| 1837 | ◐ T | April 20 | 9 A |
| — | ☉ | May 4 | 7½ A |
| — | ◐ T | Oct 13 | 11½ A |
| 1838 | ◐ P | April 10 | 2¼ M |
| — | ◐ P | Oct. 3 | 3 A |
| 1839 | ☉ | March 15 | 2½ A |
| — | ☉ | Sept. 7 | 10½ A |
| 1840 | ◐ P | Feb. 17 | 2 A |
| — | ☉ | March 4 | 4 M |
| — | ◐ P | Aug. 13 | 7½ M |
| 1841 | ◐ T | Feb. 6 | 2½ M |
| — | ☉ | Feb. 21 | 11 M |
| — | ☉ | July 18 | 2 A |
| — | ◐ T | Aug. 2 | 10 M |
| 1842 | ◐ P | Jan. 26 | 6 A |
| — | ☉ | July 8 | 7 M |
| — | ◐ P | July 22 | 11 M |
| 1843 | ◐ P | June 12 | 8 M |
| — | ◐ P | Dec. 7 | 0½ M |
| — | ☉ | Dec. 21 | 5½ M |
| 1844 | ◐ T | May 31 | 11 A |
| — | ◐ T | Nov. 25 | 0½ M |
| 1845 | ☉ | May 6 | 10½ M |
| — | ◐ T | May 21 | 4½ A |
| 1845 | ◐ P | Nov. 14 | 1 M |
| 1846 | ☉ | April 25 | 5½ A |
| — | ☉ | Oct. 20 | 8½ M |
| 1847 | ◐ P | March 31 | 9½ A |
| — | ☉ | Sept. 24 | 3 A |
| — | ☉ | Oct. 9 | 9½ M |
| 1848 | ◐ T | March 19 | 9½ A |
| — | ◐ T | Sept 13 | 6½ M |
| — | ☉ | Sept. 27 | 10 M |
| 1849 | ☉ | Feb. 23 | 1½ M |
| — | ◐ P | March 9 | 1 M |
| — | ◐ P | Sept. 2 | 5½ A |
| 1850 | ☉ | Feb. 12 | 6½ M |
| — | ☉ | Aug. 7 | 10 A |
| 1851 | ◐ P | Jan. 17 | 5 A |
| — | ◐ P | July 13 | 7½ M |
| — | ☉ | July 28 | 2½ A |
| 1852 | ◐ T | Jan. 7 | 6½ M |
| — | ◐ T | July 1 | 3¾ A |
| — | ☉ | Dec. 11 | 4 M |
| — | ◐ P | Dec. 26 | 1 A |
| 1853 | ◐ P | June 21 | 6 M |
| 1854 | ◐ P | May 12 | 4 A |
| — | ◐ P | Nov. 4 | 9½ A |
| 1855 | ◐ T | May 2 | 4½ M |
| — | ☉ | May 16 | 2½ M |
| — | ◐ T | Oct. 25 | 8 M |
| 1856 | ◐ P | April 20 | 9½ M |
| — | ☉ | Sept. 29 | 4 M |
| — | ◐ P | Oct. 13 | 11½ A |
| 1857 | ☉ | Sept. 18 | 6 M |
| 1858 | ◐ P | Feb. 27 | 10¼ A |
| — | ☉ | March 15 | 0½ A |
| — | ◐ P | Aug. 24 | 2½ A |
| 1859 | ◐ T | Feb. 17 | 11 M |
| — | ☉ | July 29 | 9½ A |
| — | ◐ T | Aug. 13 | 4½ A |
| 1860 | ◐ P | Feb. 7 | 2½ M |
| — | ☉ | July 18 | 2 A |
| — | ◐ P | Aug. 1 | 5½ A |
| 1861 | ☉ | Jan. 11 | 3½ M |
| — | ☉ | July 8 | 2 M |
| — | ◐ P | Dec. 17 | 8½ M |
| — | ☉ | Dec. 31 | 2½ A |
| 1862 | ◐ T | June 12 | 6¾ M |
| — | ◐ T | Dec. 6 | 8 M |
| — | ☉ | Dec. 21 | 5½ M |
| 1863 | ☉ | May 17 | 5 A |
| — | ◐ T | June 2 | 0 M |
| — | ◐ P | Nov. 25 | 9 M |
| 1864 | ☉ | May 6 | 0¾ M |
| 1865 | ◐ P | April 11 | 5 M |
| — | ◐ P | Oct. 4 | 11 A |

| Years. | | Months and Days. | Time. | Years. | | Months and Days. | Time. |
|---|---|---|---|---|---|---|---|
| 1865 | ☉ | Oct. 19 | 5 A | 1882 | ☉ | Nov. 11 | 0 M |
| 1866 | ☉ | March 16 | 10 A | 1883 | ◐ P | April 22 | Merid. |
| —— | ◐ T | March 31 | 5 M | —— | ◐ P | Oct. 16 | 7½ M |
| —— | ◐ T | Sept. 24 | 2½ A | —— | ☉ | Oct. 31 | 0½ M |
| —— | ☉ | Oct. 8 | 5¼ A | 1884 | ☉ | March 27 | 6 M |
| 1867 | ☉ | March 6 | 10 M | —— | ● T | April 10 | Merid |
| —— | ◐ P | March 20 | 9 M | —— | ◐ T | Oct. 4 | 10½ A |
| —— | ◐ P | Sept. 14 | 1 M | —— | ☉ | Oct. 19 | 1 M |
| 1868 | ☉ | Feb. 23 | 2½ A | 1885 | ◐ P | March 30 | 5 A |
| —— | ☉ | Aug. 18 | 5½ M | —— | ◐ P | Sept. 24 | 8½ M |
| 1869 | ◐ P | Jan. 28 | 1¾ M | 1886 | ☉ | Aug. 29 | 1½ A |
| —— | ◐ P | July 23 | 2 A | 1887 | ◐ P | Feb 8 | 10½ M |
| —— | ☉ | Aug. 7. | 10 A | —— | ◐ P | Aug. 3 | 9 A |
| 1870 | ◐ T | Jan 17 | 3 A | —— | ☉ | Aug. 19 | 6 M |
| —— | ◐ T | July 12 | 11 A | 1888 | ◐ T | Jan. 28 | 11½ A |
| —— | ☉ | Dec. 22 | 0¾ A | —— | ◐ T | July 23 | 6 M |
| 1871 | ◐ P | Jan. 6 | 9½ A | 1889 | ◐ P | Jan. 17 | 5½ M |
| —— | ☉ | June 18 | 2½ M | —— | ◐ P | July 12 | 9 A |
| —— | ◐ P | July 2 | 1½ A | —— | ☉ | Dec. 22 | 1 A |
| —— | ☉ | Dec. 12 | 4½ M | 1890 | ◐ P | June 23 | 6 M |
| 1872 | ◐ P | May 22 | 11½ A | —— | ☉ | June 17 | 10 M |
| —— | ☉ | June 6 | 3½ M | —— | ◐ P | Nov. 26 | 2 A |
| —— | ◐ P | Nov. 15 | 5¾ M | 1891 | ◐ T | May 23 | 7 A |
| 1873 | ◐ T | May 12 | 11½ M | —— | ☉ | June 6 | 4½ A |
| —— | ☉ | May 26 | 9½ M | —— | ◐ T | Nov. 16 | 0¾ M |
| —— | ◐ T | Nov. 4 | 4½ A | 1892 | ◐ P | May 11 | 11½ A |
| 1874 | ◐ P | May 1 | 4½ A | —— | ◐ T | Nov. 4 | 4½ A |
| —— | ☉ | Oct. 10 | 11½ M | 1893 | ☉ | April 16 | 3 A |
| —— | ◐ P | Oct. 25 | 8 M | 1894 | ◐ P | March 21 | 2½ A |
| 1875 | ☉ | April 6 | 7 M | —— | ☉ | April 6 | 4½ M |
| —— | ☉ | Sept. 29 | 1½ A | —— | ◐ P | Sept 15 | 4¾ M |
| 1876 | ◐ P | March 10 | 6½ M | —— | ☉ | Sept. 29 | 5½ M |
| —— | ◐ P | Sept. 3 | 9½ A | 1895 | ◐ T | March'11 | 4 M |
| 1877 | ◐ T | Feb. 27 | 7½ A | —— | ☉ | March 26 | 10 M |
| —— | ☉ | March 15 | 3 M | —— | ☉ | Aug. 20 | 0½ A |
| —— | ☉ | Aug. 9 | 5 M | —— | ◐ T | Sept. 4 | 6 M |
| —— | ◐ T | Aug. 23 | 11½ A | 1896 | ◐ P | Feb. 28 | 8 A |
| 1878 | ◐ P | Feb. 17 | 11½ M | —— | ☉ | Aug. 9 | 4½ M |
| —— | ☉ | July 29 | 9½ A | —— | ◐ P | Aug. 23 | 7 M |
| —— | ◐ P | Aug. 13 | 0½ M | 1897 | No visible Eclipse. | | |
| 1879 | ☉ | Jan. 22 | Merid. | 1898 | ◐ P | Jan. 8 | 0½ M |
| —— | ☉ | July 19 | 9 M | —— | ☉ | Jan. 22 | 8 M |
| —— | ◐ P | Dec. 28 | 4½ A | —— | ◐ P | July 3 | 9½ A |
| 1880 | ☉ | Jan. 11 | 11 A | —— | ◐ T | Dec. 27 | 12 A |
| —— | ◐ T | June 22 | 2 A | 1899 | ☉ | Jan. 11 | 11 A |
| —— | ◐ T | Dec. 16 | 4 A | —— | ☉ | June 8 | 7 M |
| —— | ☉ | Dec. 31 | 2 A | —— | ◐ T | June 23 | 2½ A |
| 1881 | ☉ | May 28 | 0 M | —— | ◐ P | Dec. 17 | 1½ M |
| —— | ◐ T | June 12 | 7¼ M | 1900 | ☉ | May 28 | 3¼ A |
| —— | ◐ P | Dec. 5 | 5½ A | —— | ◐ P | June 13 | 4 M |
| 1882 | ☉ | May 17 | 8 M | —— | ☉ | Nov. 22 | 8 M |

## PROBLEM LV.

*To find the time of the year when the Sun or Moon will be liable to be eclipsed.*

Rule. Find the place of the moon's nodes, the time of *new moon*, and the sun's longitude at that time, by an ephemeris;* then if the sun be within 17 degrees of the moon's node, there will be an eclipse of the sun.

2. Find the place of the moon's nodes, the time of full moon, and the sun's longitude at that time, by an ephemeris; then if the sun's longitude be within 12 degrees of the moon's node, there will be an eclipse of the moon.

### Or, without the ephemeris.

The mean annual variation of the moon's nodes is 19° 19′ 44″ (*page* 147) and the place of the node for the first of January 1825 being 29° 42′ in ♐, its place for any other time may therefore be found.

The time of *new moon* may be found as directed at *page* 176, and the sun's longitude is the sun's place in the ecliptic.† The rest may be found as above.

Examples. 1. On the 21st of May, 1826, there will be a full moon, at which time the place of the Moon's node is 2° 56′ in ♐, and the sun's longitude ♉ 29° 58′; will an eclipse of the moon happen at that time?

*Answer.* Here the sun's longitude is within 3 degrees nearly of the moon's node, therefore there will be an eclipse of the moon.—When the sun is in one of the moon's nodes at the time of full moon, the moon is in the other node, and the earth is directly between them.

2. It appears from the table (*page* 181) that there will be a new moon on the 6th of May, 1826, at which time the place of the moon's node will be ♐ 3° 45′, and the sun's longitude ♉ 15° 58′; will there be an eclipse of the sun at that time?

3. There will be a new moon on the 5th of June, 1826, at which time the place of the moon's node will be ♐ 2° 8′ and the

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* White's Ephemeris, or the Nautical Almanac.

† The moon's longitude may be found thus: multiply 12° 11′ 6″ by the moon's age (*see pages* 91 and 176), the product will give the number of degrees by which the moon's longitude exceeds that of the sun.

sun's longitude ♊ 14° 27′; will there be an eclipse of the sun at that time?

4. On the 14th of November 1826, there will be a full moon, at which time the place of the moon's node will be ♏ 23° 34′, and the sun's longitude ♏ 21° 47′: will there be an eclipse of the moon at that time?

5. On the 28th of November 1826, there will be a new moon at which time the place of the moon's node is ♏ 22° 44′, and the sun's longitude ♐ 6° 46′; will there be an eclipse of the sun at that time?

6. On the 28th of December 1826, there will be a new moon, at which time the place of the moon's node is ♏ 21° 14′, and the sun's longitude ♑ 6° 44′; will there be an eclipse of the sun at that time?

## PROBLEM LVI.

### *To explain the phenomenon of the harvest moon.*

Definition 1. The harvest moon, in north latitude, is the full moon which happens at, or near, the time of the autumnal equinox; for, to the inhabitants of north latitude, whenever the moon is in Pisces or Aries (and she is in these signs twelve times in a year,) there is very little difference between her times of rising for several nights together, because her orbit is at these times nearly parrallel to the horizon. This peculiar rising of the moon passes unobserved at all other times of the year except in September and October; for there never can be a full moon except the sun be directly opposite to the moon; and as this particular rising of the moon can only happen when the moon is in ♓ Pices or ♈ Aries, the sun must necessarily be either in ♍ Virgo or ♎ Libra at that time, and these signs answer to the months of September and October.

Definition 2. The harvest moon, in south latitude, is the full moon which happens at, or near, the time of the vernal equinox; for, to the inhabitants of south latitude, whenever the moon is in ♍ Virgo or ♎ Libra (and she is in these signs twelve times in the year), her orbit is nearly parallel to the horizon; but when the full moon happens in ♍ Virgo or ♎ Libra, the sun must be either in ♓ Pisces or ♈ Aries. Hence it appears that the harvest moons are just as regular in south latitude as they are in north latitude, only they happen at contrary times of the year.

RULE FOR PERFORMING THE PROBLEM.—1. *For north latitude.* Elevate the north pole to the latitude of the place, put a patch or make a mark in the ecliptic on the point Aries, and upon every twelve* degrees preceding and following that point, till there be ten or eleven marks; bring that mark which is nearest to Pisces to the eastern edge of the horizon, and set the index to 12; turn the globe westward till the other marks successively come to the horizon, and observe the hours passed over by the index; the intervals of time between the marks coming to the horizon will show the diurnal difference of time between the moon's rising. If these marks be brought to the western edge of the horizon in the same manner, you will see the diurnal difference of time between the moon's setting; for, when there is the smallest difference between the times of the moon's rising,† there will be the greatest difference between the times of her setting; and, on the contrary, when there is the greatest difference between the times of the moon's rising, there will be the least difference between the times of her setting.

NOTE. As the moon's nodes vary their position and form a complete revolution in about nineteen years, there will be a regular period of all the varieties which can happen in the rising and setting of the moon during that time. The following table (extracted from Ferguson's Astronomy) shows in what years the harvest moons are the least and most beneficial, with regard to the times of their rising from 1823 to 1860. The colums of years under the letter L are those in which the harvest moons are least beneficial, because they fall about the descending node; and those under M are the most beneficial, because they fall about the ascending node.

| L | L | L | L | M | M | M | M |
|---|---|---|---|---|---|---|---|
| 1826 | 1831 | 1845 | 1849 | 1823 | 1837 | 1842 | 1856 |
| 1827 | 1832 | 1846 | 1850 | 1824 | 1838 | 1843 | 1857 |
| 1828 | 1833 | 1847 | 1851 | 1825 | 1839 | 1853 | 1858 |
| 1829 | 1834 | 1848 | 1852 | 1835 | 1840 | 1854 | 1859 |
| 1830 | 1844 | | | 1836 | 1841 | 1855 | 1860 |

2. *For south latitude.* Elevate the south pole to the latitude of the place, put a patch or make a mark on the ecliptic on the point Libra, and upon every twelve degrees preceding and following that point, till there be ten or eleven marks; bring that mark which is nearest to Virgo, to the eastern edge of the horizon, and

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* The reason why you mark every 12 degrees is, that the moon gains 12° 11′ of the sun in the ecliptic every day (see the 2d note, p. 80.)

† At London, when the moon rises in the point Aries, the ecliptic at that point makes an angle of only 15 degrees with the horizon, but when she sets in the point Aries, it makes an angle of 62 degrees: and when the moon rises in the point Libra, the ecliptic, at that point, makes an angle of 62 degrees with the horizon; but, when she sets in the point Libra, it only makes an angle of 15 degrees with the horizon.

set the index to 12; turn the globe westward till the other marks successively come to the horizon, and observe the hours passed over by the index; the intervals of time between the marks coming to the horizon, will be the diurnal difference of time between the moon's rising, &c. as in the foregoing part of the problem.*

## PROBLEM LVII.

*The day and hour of an eclipse of any one of the satellites of Jupiter being given, to find upon the globe all those places where it will be visible.*

Rule. Find the sun's declination for the given day, and elevate the pole to that declination; bring the place at which the hour is given to the brass meridian, and set the index of the hour circle to 12; then, if the given time be before noon, turn the globe westward as many hours as it wants of noon; if after noon, turn the globe eastward as many hours as it is past noon; fix the globe in this position: Then,

1. *If Jupiter rise after the sun*†, that is if he be an evening star, draw a line along the *eastern edge of the horizon* with a black lead pencil, this line will pass over all places on the earth where the sun is setting at the given hour; turn the globe westward on its axis till as many degrees of the equator have passed under the brass meridian as are equal to the difference between the sun's and Jupiter's right ascension; keep the globe from revolving on its axis, and elevate the pole as many degrees above the horizon as are equal to Jupiter's declination, then draw an other line with a pencil along the eastern edge of the horizon: the eclipse will be visible to every place between these lines, viz. from the time of the sun's setting to the time of Jupiter's setting.

2. *If Jupiter rise before the sun*‡, that is, if he be a morning star, draw a line along the *western edge of the horizon* with a black lead

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* This solution is on a supposition that the moon keeps constantly in the ecliptic, which is sufficiently accurate for illustrating the problem. Otherwise the latitude and longitude of the moon, or her right ascension and declination, may be taken from the Ephemeris, at the time of full moon, and a few days preceding and following it; her place will then be truly marked on the globe.

† Jupiter rises after the sun, when his longitude is greater than the sun's longitude.

‡ Jupiter rises before the sun, when his longitude is less than the sun's longitude.

pencil, this line will pass over all places of the earth where the sun is rising at the given hour; turn the globe eastward on its axis till as many degrees of the equator have passed under the brass meridian as are equal to the difference between the sun's and Jupiter's right ascension; keep the globe from revolving on its axis, and elevate the pole as many degrees above the horizon as are equal to Jupiter's declination, then draw an other line with a pencil along the western edge of the horizon: the eclipse will be visible to every place between these lines, viz. from the time of Jupiter's rising to the time of the sun's rising.

*Examples.* 1. On the 13th of January, 1805, there was an *immersion* of the first satellite of Jupiter at 9 m. 3. sec. past five o'clock in the *morning* at Greenwich; where was it visible?

*Answer.* In this example the longitude of the sun exceeds the longitude of Jupiter, therefore Jupiter was a morning star, his declination being 19° 16′ S. and his longitude 7 signs 29° 46′, by the Nautical Almanac: his right ascension and the sun's right ascension may be found by the globe; for, if Jupiter's longitude in the ecliptic be brought to the brass meridian, his place will stand under the degree of his declination;* and his right ascension will be found on the equator, reckoning from Aries. This eclipse was visible at Greenwich, the greater part of Europe, the west of Africa, Cape Verd Islands, &c.

2. On the 18th of January, 1826, at 4 m. 49 sec. past three o'clock in the *morning* at Greenwich, there will be an immersion of the first satellite of Jupiter; where will the eclipse be visible? Jupiter's longitude at that time being 5 signs 13° 51′ and his declination 7° 33′ north.

3. On the 13th of April, 1826, at 5 m. 5 sec. past four o'clock in the morning, at Greenwich, there will be an emersion of the first satellite of Jupiter; where will the eclipse be visible? Jupiter's longitude at that time being 5 signs 4° 55′ and his declination 11° north.

4. On the 20th of November, 1826, at 31 min. 13 sec. past nine o'clock in the morning, at Greenwich, there will be an immersion of the second satellite of Jupiter; where will the eclipse be visible? Jupiter's longitude at that time being 6 signs 7° 38′, and his declination 1° 57′ north.

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* This is on supposition that Jupiter moves in the ecliptic, and as he deviates but little therefrom, the solution by this method will be sufficiently accurate. To know if an eclipse of any one of the satellites of Jupiter will be visible at any place, we are directed by the Nautical Almanac to "find whether Jupiter be 88° above the horizon of the place, and the sun as much below it."

## PROBLEM LVIII.

*To place the terrestrial globe in the* SUNSHINE, *so that it may represent the* NATURAL POSITION *of the earth.*

RULE. If you have a meridian line* drawn upon a horizontal plane, set the north and south points of the wooden horizon of the globe directly over this line; or, place the globe directly north and south by the mariner's compass, taking care to allow for the variation; bring the place in which you are situated to the brass meridian, and elevate the pole to its latitude; then the globe will correspond in every respect with the situation of the earth itself. The poles, meridians, parallel circles, tropics, and all the circles on the globe, will correspond with the same imaginary circles in the heavens; and each point, kingdom, and state, will be turned towards the real one, which it represents.

While the sun shines on the globe, one hemisphere will be enlightened, and the other will be in the shade: thus, at one view, may be seen all places on the earth which have day, and those which have night.†

If a needle be placed perpendicularly in the middle of the enlightened hemisphere, (which must of course be upon the parallel of the sun's declination for the given day,) it will cast no shadow, which shows that the sun is vertical at that point; and if a line be drawn through this point from pole to pole, it will be the meridian of the place where the sun is vertical, and every place upon this line will have noon at that time; all places to the west of this line will have morning, and all places to the east of it afternoon. Those inhabitants who are situated on the circle which is the boundary between light and shade, to the westward of the meridian where the sun is vertical, will see the sun rising; those in the same circle to the eastward of this meridian will see the sun setting; those inhabitants towards the north of the circle, which is the boundary between light and shade, will perceive the sun to the southward of them, in the horizon; and those who are in the same circle towards the south, will see the sun in a similar manner to the north of them.

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* A a meridian line is useful for fixing a horizontal dial, and for placing a globe directly north and south, &c. the different methods of drawing a line of this kind will precede the problems on dialling.

† For this part of the problem it would be more convenient if the globe could be properly supported without the frame of it, because the shadow of its stand, and that of its horizon, will darken several parts of the surface of the globe, which would otherwise be enlightened.

If the sun shine beyond the north pole at the given time, his declination is as many degrees north as he shines over the pole; and all places at that distance from the pole will have constant day, till the sun's declination decreases, and those at the same distance from the south pole will have constant night.

If the sun do not shine so far as the north pole at the given time, his declination is as many degrees south as the enlightened part is distant from the pole; and all places within the shade near the pole, will have constant night, till the sun's declination increases northward. While the globe remains steady in the position it was first placed when the sun is westward of the meridian, you may perceive on the east side of it, in what manner the sun gradually departs from place to place as the night approaches; and when the sun is eastward of the meridian, you may perceive on the western side of it, in what manner the sun advances from place to place as the day approaches.

## PROBLEM LIX.

*The latitude of a place being given, to find the hour of the day at any time when the* SUN SHINES.

RULE. 1. Place the north and south points of the horizon of the globe directly north and south upon a horizontal plane, by a meridian line, or by a mariner's compass, allowing for the variation, and elevate the pole to the latitude of the place; then, if the place be in north latitude, and the sun's declination be north, the sun will shine over the north pole; and if a long pin be fixed perpendicularly in the direction of the axis of the earth, and in the centre of the hour circle, its shadow will fall upon the hour of the day, the figure XII of the hour circle being first set to the brass meridian. If the place be in north latitude, and the sun's declination be above ten degrees south, the sun will not shine upon the hour circle at the north pole.

RULE 2. Place the globe due north and south upon a horizontal plane, as before, and elevate the pole to the latitude of the place; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to XII; stick a needle perpendicularly in the sun's place in the ecliptic, and turn the globe on its axis till the needle casts no shadow; fix the globe in this position and the index will show the hour before 12 in the morning, or after 12 in the afternoon.

Rule 3. Divide the equator into 24 equal parts from the point Aries, on which place the number VI; and proceed westward VII, VIII, IX, X, XI, XII, I, II, III, IV, V, VI, which will fall upon the point Libra, VII, VIII, IX, X, XI, XII, I, II, III, IV, V*; elevate the pole to the latitude, place the globe due north and south upon a horizontal plane, by a meridian line, or a good mariner's compass, allowing for the variation, and bring the point Aries to the brass meridian; then observe the circle which is the boundary between light and darkness westward of the brass meridian; and it will intersect the equator in the given hour in the morning; but, if the same circle be eastward of the meridian, it will intersect the equator in the given hour in the afternoon.

Or, Having placed the globe upon a true horizontal plane, set it due north and south by a meridian line; elevate the pole to the latitude, and bring the point Aries to the brass meridian, as before; then tie a small string, with a noose, round the elevated pole, stretch its other end beyond the globe, and move it so that the shadow of the string may fall upon the depressed axis: at that instant its shadow upon the equator will give the hour.†

## PROBLEM LX.

### *To find the sun's altitude, by placing the globe in the* SUNSHINE.

Rule. Place the globe upon a truly horizontal plane, stick a needle perpendicularly over the north pole‡, in the direction of the axis of the globe, and turn the pole towards the sun, so that the shadow of the needle may fall upon the middle of the brass

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* On *Adams'* globes the antarctic circle is thus divided, by which this problem may be solved.

† The learner must remember that the time shown in this problem is solar time, as shown by a sun dial; and, therefore, to agree with a good clock or watch, it must be corrected by a table of equation of time. See a table of this kind among the succeeding problems.

‡ It would be an improvement on the globes were our instrument-makers to drill a very small hole in the brass meridian over the north pole.

## PROBLEM LXIII.

*To make a horizontal dial for any latitude.*

Definitions and Observations.—Dialling, or the art of constructing dials, is founded entirely on astronomy; and, as the art of measuring time is of the greatest importance, so the art of dialling was formerly held in the highest esteem, and the study of it was cultivated by all persons who had any pretensions to science. Since the invention of clocks and watches, dialling has not been so much attended to, though it will never be entirely neglected; for, as clocks and watches are liable to stop and go wrong, that unnerring instrument, a true sun-dial, is used to correct and to regulate them.

Suppose the globe of the earth to be transparent (as represented by *Fig*. 4. *in Plate* II.) with the hour circles, or meridians, &c. drawn upon it, and that it revolves round a real axis NS, which is opaque and casts a shadow; it is evident that, whenever the edge of the plane of any hour circle or meridian points exactly to the sun, the shadow of the axis will fall upon the opposite hour circle or meridian. Now, if we imagine any opaque plane to pass through the centre of this transparent globe, the shadow of half the axis NE will always fall upon one side or other of this intersecting plane.

Let ABCD represent the plane of the horizon of London, BN the elevation of the pole or latitude of the place: so long as the sun is above the horizon, the shadow of the upper half NE of the axis will fall somewhere upon the upper side of the plane ABCD. When the edge of the plane of any hour circle, as F, G, H, I, K, L, M, O, points directly to the sun, the shadow of the axis, which axis is coincident with this plane, marks the respective hour line upon the plane of the horizon ABCD: the hour line upon the horizontal plane is, therefore, a line drawn from the centre of it, to that point where this plane intersects the meridian opposite to that on which the sun shines. Thus, when the sun is upon F, the meridian of London, the shadow of NE the axis will fall upon E, XII. By the same method, the rest of the hour lines are found, by drawing, for every hour a line from the centre of the horizontal plane to that meridian, which is diametrically opposite to the meridian pointing exactly to the sun. If, when the hour circles are thus found, all the lines be taken away except the semi-axis NE, what remains will be a horizontal dial for the given place.

From what has been premised, the following observations naturally arise:

1. The gnomon of every sun-dial must always be parallel to the axis of the earth, and must point directly to the two poles of the world.

2. As the whole earth is but a point when compared with the heavens, therefore, if a small sphere of glass be placed on any part of the earth's surface, so that its axis be parallel to the axis of the earth, and the sphere have such lines upon it, and such a plane within it as above described; it will show the hour of the day as truly as if it were placed at the centre of the earth, and the body of the earth were as transparent as glass.

3. In every horizontal dial the angle which the style, or gnomon, makes with the horizontal plane, must always be equal to the latitude of the place for which the dial is made.

Rule for performing the problem.—Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; bring the point Aries to the brass meridian; then, as globes in general[*] have meridians drawn through every 15 degrees of longitude, eastward and westward from the point of Aries, observe where these meridians intersect the horizon, and note the number of degrees between each of them; the arcs between the respective hours will be equal to these degrees. The dial must be numbered XII at the brass meridian, thence XI, X, IX, VIII, VII, VI, V, IV, &c. towards the west, for morning hours; and I, II, III, IV, V, VI VII, VIII, &c. for evening hours. No more hour lines need be drawn than what will answer to the sun's continuance above the horizon on the longest day at the given place. The style or gnomon of the dial must be fixed in the centre of the dial-plate, and make an angle therewith equal to the latitude of the place. The face of the dial may be of any shape, as round, elliptical, square, oblong, &c. &c.

Example. To make a horizontal dial for the latitude of London.

Having elevated the pole 51½ degrees above the horizon, and brought the point Aries to the brass meridian, you will find the meridians on the eastern part of the horizon, reckoning from 12, to be 11° 50′, 24° 20′, 38° 3′, 53° 35′, 71° 6′, and 90°, for the hours I, II, III, IV, V, and VI; or, if you count from the east towards the be 0°, 18° 54′, 36° 25′, 51° 57′, 65° 40′, and 78° 10′, for the hours II, I, reckoning from VI o'clock backward to XII. There is no the distances farther than VI, because the distances from XII to on are exactly the same as from XII to VI in the afternoon ; and ued through the centre of the dial are the hours on the opposite

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[*] On *Cary's* large globes, the meridians are drawn through every *ten* degrees, an alteration which answers no useful purpose whatever, and is in many cases very inconvenient. To solve this problem, by these globes, meridians must be drawn through every *fifteen* degrees with a pencil.

g Table, calculated by spherical trigonometry, contains not only ut the halves and quarters from XII to VI.

| Hou s. | Hour Angles. | Hour Arcs. | Hours. | Hour Angles. | Hour Arcs. |
|---|---|---|---|---|---|
| XII | 0° 0′ | 0 | 3¼ | 48 45′ | 41 45′ |
| 12¼ | 3 45 | 2 | 3½ | 52 30 | 45 34 |
| 12½ | 7 30 | 5 | 3¾ | 56 15 | 49 30 |
| 12¾ | 11 15 | 8 | | 60 0 | 53 35 |
| I | 15 0 | 11 | 4¼ | 63 45 | 57 47 |
| 1¼ | 18 45 | 14 | 4½ | 67 30 | 62 6 |
| 1½ | 22 30 | 17 | 4¾ | 71 15 | 67 33 |
| 1¾ | 26 15 | 21 | | 75 0 | 71 6 |
| II | 30 0 | 24 | 5¼ | 78 45 | 75 45 |
| 2¼ | 33 45 | 27 | 5½ | 82 30 | 80 25 |
| 2½ | 37 30 | 31 | 5¾ | 86 15 | 85 13 |
| 2¾ | 41 15 | 34 28 | | 90 0 | 90 0 |
| III | 45 0 | 38 3 | | | |

The calculation of the hour arcs by spherical trigonometry is extremely easy; for while the globe remains in the position above described, it will be seen that a right angled spherical triangle is formed, the perpendicular of which is the latitude, its base the hour arc, and its verticl angle the hour angle. Hence,

Radius, sine of 90°
Is to sine of the latitude;
As tangent of the hour angle,
Is to the tangent of the hour arc on the horizon.

It may be observed here, that if a horizontal dial, which shows the hour by the top of the perpendicular gnomon, be made for a place in the torrid zone, whenever the sun's declination exceeds the latitude of the place, the shadow of the gnomon will *go back* twice in the day, once in the forenoon and once in the afternoon ; and the greater the difference between the latitude and the sun's declination is, the farther the shadow will go back. In the 38th chapter of Isiah, *Hezekiah* is promised that his life shall be prolonged 15 years, and as a sign of this, he is also promised that the shadow of the sun-dial of *Ahaz* shall go back ten degrees. This was truly, as it was then considered a *miracle;* for, as *Jerusalem*, the place where the dial of *Ahaz* was erected, was out of the torrid zone, the shadow could not possibly go back from any natural cause.

## PROBLEM LXIV.

*To make a vertical dial facing the south, in north latitude.*

**Definitions and Observations.**—The horizontal dial, as described in the preceding problem, was supposed to be placed upon a pedestal, and as the sun always shines upon such a dial when he is above the horizon, provided no objects intervene, it is the most complete of all kinds of dials. The next in utility is the vertical dial facing the south in north latitudes; that is, a dial standing against the wall of a building which exactly faces the south.

Supposing the globe to be transparent, as in the foregoing problem (*see Fig.* 5. *Plate* II.) with the hour circles or meridians F, G, H, I, K, L, M, O, &c. drawn upon it; ABCD an opaque vertical plane perpendicular to the horizon, and passing through the centre of the globe. While the globe revolves round its axis NS, it is evident that, if the semi-axis ES be opaque and cast a shadow, this shadow will always fall upon the plane ABC, and mark out the hours as in the preceding problem. By comparing *Fig.* 5. with *Fig.* 4. in *Plate* II. it will appear that the plane surface of every dial whatever, is parallel to the horizon of some place or other upon the earth, and that the elevation of the style or gnomon above the dial's surface, when it faces the south, is always equal to the latitude of the place whose horizon is parallel to that surface. Thus it appears that SP, which is the co-latitude of London, is the latitude of the place whose horizon is represented by the plane ADCB: for, let the south pole of the globe be elevated 38½ degrees above the southern point of the horizon, and the point Aries be brought to the brass meridian; then, if the globe be placed upon a table, so as to rest on the south point of the wooden horizon, it will have exactly the appearance of *Fig.* 5. *Plate* II.; the wooden horizon, will represent the opaque plane ABCD, the south point will be at B, and the north point at D under London, the east point at C, and the west point at A. Hence we have the following

RULE FOR PERFORMING THE PROBLEM.—If the place be in north latitude, elevate the south pole to the complement of that latitude; bring the point Aries to the brass meridian; then supposing meridians to be drawn through every fifteen degrees of longitude, eastward and westward from the point Aries (as is generally the case); observe where these meridians intersect the horizon, and note the number of degrees between each of them; the arcs between the respective hours will be equal to these degrees. The dial must be numbered XII, at the brass meridian, thence XI, X, IX, VIII, VII, VI, towards the west, for morning hours; and I, II, III, IV, V, VI, towards the east, for evening hours. As the sun cannot shine longer upon such a dial as this than from VI in the morning to VI in the evening, the hour lines need not be extended any farther.

**Example.** To make a vertical dial for the latitude of London.

Elevate the south pole 38½ degrees above the horizon, and bring the point Aries to the brass meridian; then the meridians will intersect the horizon, reckoning from the south towards the east, in the following degrees; 9° 28′, 19° 45′, 31° 54′, 47° 9′, 66° 42′, and 90°, for the hours I, II, III, IV, V, VI: or if you count from the east towards the south, they will be 0°, 23° 18′, 42° 51′, 58° 6′, 70° 15′, 80° 42′, for the hours VI, V, IV, III, II, I. The distances from XII to VI in the forenoon are exactly the same as the distances from XII to VI in the afternoon.

The following table contains not only the hour arcs, but the halves and quarters from XII to VI; it is calculated exactly in the same manner as the table in the preceding problem, using the complement of the latitude instead of the latitude.

| Hours. | Hour Angles. | Hour Arcs. | Hours. | Hour Angles | Hour Arcs. |
|---|---|---|---|---|---|
| XII | 0° 0′ | 0° 0′ | 3¼ | 48° 45′ | 35° 22′ |
| 12¼ | 3 45 | 2 20 | 3½ | 52 30 | 39 3 |
| 12½ | 7 30 | 4 41 | 3¾ | 56 15 | 42 58 |
| 12¾ | 11 15 | 7 3 | IV | 60 0 | 47 9 |
| I | 15 0 | 9 28 | 4¼ | 63 45 | 51 36 |
| 1¼ | 18 45 | 11 56 | 4½ | 67 30 | 56 20 |
| 1½ | 22 30 | 14 27 | 4¾ | 71 15 | 61 23 |
| 1¾ | 26 15 | 17 4 | V | 75 0 | 66 43 |
| II | 30 0 | 19 45 | 5¼ | 78 44 | 72 17 |
| 2¼ | 33 45 | 22 35 | 5½ | 82 30 | 78 3 |
| 2½ | 37 30 | 25 32 | 5¾ | 86 15 | 84 0 |
| 2¾ | 41 15 | 28 38 | VI | 90 0 | 90 0 |
| III | 45 0 | 31 54 | | | |

The student will recollect that the time shown by a sun-dial is not the exact time of the day, as shown by a watch or clock (see Definitions 55, 56, and 57, page 35.) A good clock measures time equeally, but a sun-dial (though used for regulating clocks and watches) measures time unequally. The following table will show to the nearest minute how much a clock should be faster or slower than a sun-dial; such a table should be put upon every horizontal sun-dial.

| Days and Months. | Minutes. | Days and Months. | Minutes. | Days and Months. | Minutes. | Days and Months. | Minutes. |
|---|---|---|---|---|---|---|---|
| Jan. 1 | 4 | April 1 | 4 Clock faster. | Aug. 9 | 5 Clock faster. | Oct. 27 | 16 |
| 3 | 5 | 4 | 3 | 15 | 4 | Nov. 15 | 15 |
| 5 | 6 | 7 | 2 | 20 | 3 | 20 | 14 Clock slower than the Dial. |
| 7 | 7 | 11 | 1 | 24 | 2 | 24 | 13 |
| 9 | 8 | 15 | 0 | 28 | 1 | 27 | 12 |
| 12 | 9 |  |  | 31 | 0 | 30 | 11 |
| 15 | 10 Clock faster than the Dial. | * |  | * |  | Dec. 2 | 10 |
| 18 | 11 | 19 | 1 | Sept. 3 | 1 | 5 | 9 |
| 21 | 12 | 24 | 2 Clock slower. | 6 | 2 Clock slower than the Dial. | 7 | 8 |
| 25 | 13 | 30 | 3 | 9 | 3 | 9 | 7 |
| 31 | 14 | May 13 | 4 | 12 | 4 | 11 | 6 |
| Feb. 10 | 15 | 29 | 3 | 15 | 5 | 13 | 5 |
| 21 | 14 | June 5 | 2 | 18 | 6 | 16 | 4 |
| 27 | 13 | 10 | 1 | 21 | 7 | 18 | 3 |
| Mar. 4 | 12 | 15 | 0 | 24 | 8 | 20 | 2 |
| 8 | 11 | * |  | 27 | 9 | 22 | 1 |
| 12 | 10 | 20 | 1 Clock faster. | 30 | 10 | 24 | 0 |
| 15 | 9 | 25 | 2 | Oct. 3 | 11 | * |  |
| 19 | 8 | 29 | 3 | 6 | 12 | 26 | 1 Cl. faster. |
| 22 | 7 | July 5 | 4 | 10 | 13 | 28 | 2 |
| 25 | 6 | 11 | 5 | 14 | 14 | 30 | 3 |
| 28 | 5 | 28 | 6 | 19 | 15 |  |  |

Dials may be constructed on all kinds of planes, whether horizontal or inclined; a vertical dial may be made to face the south, or any point of the compass; but the two dials already described are the most useful. To acquire a complete knowledge of dialling, the gnomonical projection of the sphere, and the principles of spherical trigonometry, must be thoroughly understood; these preliminary branches may be learned from *Emerson's* Gnomonical Projection, and *Keith's* Trigonometry. The writers on dialling are very numerous; the last and best treatise on the subject is *Emerson's*.

## CHAPTER II.

### *Problems performed by the Celestial Globe.*

### PROBLEM LXV.

*To find the right ascension and declination of the sun*, or a star.*

Rule. Bring the sun or star to that part of the brass meridian which is numbered from the equinoctial towards the poles; the degree on the brass meridian is the declination, and the number of degrees on the equinoctial, between the brass meridian and the point Aries, is the right ascension.

Or, Place both the poles of the globe in the horizon, bring the sun or star to the eastern part of the horizon; then the number of degrees which the sun or star is northward or southward of the east, will be the declination north or south; and the degrees on the equinoctial, from Aries to the horizon, will be the right ascension.

Examples. 1. Required the right ascension and declination of *a Dubhe*, in the back of the Great Bear.

*Answer.* Right ascension 162° 49′, declination 62° 48′ N.

2. Required the right ascensions and declinations of the following stars:

γ, *Algenib*, in Pegasus.
a, *Scheder*, in Cassiopeia.
β, *Mirach*, in Andromeda.
a, *Acherner*, in Eridanus.
a, *Menkar*, in Cetus.
β, *Algol*, in Perseus.
a, *Aldebaran*, in Taurus.
a, *Capella*, in Auriga.
β, *Rigel*, in Orion.
γ, *Bellatrix*, in Orion.
a, *Betelgeux*, in Orion.
a, *Canopus*, in Argo Navis.
a, *Procyon*, in the Little Dog.
γ, *Algorab*, in the Crow.
a, *Arcturus*, in Boötes.
ε, *Vendemiatrix*, in Virgo.

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* The right ascensions and declinations of the moon and planets must be found from an ephemeris; because, by their continual change of situation, they cannot

## PROBLEM LXVI.

### *To find the latitude and longitude of a star.**

Rule. Place the upper end of the quadrant of altitude on the north or south pole of the ecliptic, according as the star is on the north or south side of the ecliptic, and move the other end till the star comes to the graduated edge of the quadrant; the number of degrees between the ecliptic and the star is the latitude; and the number of degrees on the ecliptic, reckoned eastward from the point Aries to the quadrant, is the longitude.

Or, Elevate the north or south pole 66½° above the horizon; according as the given star is on the north or south side of the ecliptic; bring the pole of the ecliptic to that part of the brass meridian which is numbered from the equinoctial towards the pole; then the ecliptic will coincide with the horizon; screw the quadrant of altitude upon the brass meridian over the pole of the ecliptic; keep the globe from revolving on its axis, and move the quadrant till its graduated edge comes over the given star; the degree on the quadrant cut by the star is its latitude; and the sign and degree on the ecliptic cut by the quadrant show its longitude.

Examples. 1. Required the latitude and longitude of *a Aldebaran* in Taurus.

*Answer.* Latitude 5° 28′ S., longitude 2 signs 6° 53′; or 6° 53′ in Gemini.

2. Required the latitudes and longitudes of the following stars.

*a*, *Markab*, in Pegasus.
*β*, *Scheat*, in Pegasus.
*a*, *Fomalhaut*, in the S. Fish.
*a*, *Deneb*, in Cygnus.
*a*, *Altair*, in the Eagle.
*β*, *Albireo*, in Cygnus.
*a*, *Vega*, in Lyra.
*γ*, *Rastaben*, in Draco.
*a*, *Antares*, in the Scorpion.
*a*, *Arcturus*, in Boötes.
*β*, *Pollux*, in Gemini.
*β*, *Rigel*, in Orion.

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* The latitudes and longitudes of the planets must be found from an ephemeris.

## PROBLEM LXVII.

*The right ascension and declination of a star, the moon, a planet, or of a comet, being given, to find its place on the globe.*

**Rule.** Bring the given degrees of right ascension to that part of the brass meridian which is numbered from the equinoctial towards the poles; then under the given declination on the brass meridian you will find the star, or place of the planet.

**Examples.** 1. What star has 261° 29′ of right ascension, and 52° 27′ north declination?

*Answer.* β in Draco.

2. On the 31st of January, 1825, the moon's right ascension was 91° 21′, and her declination 23° 19′ N.; find her place on the globe at that time.

*Answer.* In the milky way, a little above the left foot of Castor.

3. What stars have the following right ascensions and declinations?

| Right Ascensions. | Declinations. | Right Ascensions. | Declinations. |
|---|---|---|---|
| 7° 19′ | 55° 26′ N. | 83° 6′ | 34° 11′ S. |
| 11 11 | 59 38 N. | 86 13 | 44 55 N. |
| 25 54 | 19 50 N. | 99 5 | 16 26 S. |
| 46 32 | 9 34 S. | 110 27 | 32 19 N. |
| 53 54 | 23 19 N. | 113 16 | 28 30 N. |
| 74 14 | 8 27 S. | 129 2 | 7 8 N. |

4. On the seventh of March, 1826, the moon's right ascension at midnight will be 333° 2′, and her declination 5° 44′ S.; find her place on the globe.

5. On the 13th of May, 1826, the declination of Venus will be 22° 11′ N., and her right ascension 66° 45′; find her place on the globe at that time.

6. On the first of July, 1826, the declination of Jupiter will be 9° 4′ N., and his right ascension 161° 30′; find his place on the globe at that time.

## PROBLEM LXVIII.

*The latitude and longitude of the moon, a star, or of a planet, being given, to find its place on the globe.*

Rule. Place the division of the quadrant of altitude marked [redacted] pole of the ecliptic; then, under the given latitude, on the graduated edge of the quadrant, you will find the star, or place of the moon or planet.

**Examples.** 1. What star has 0 signs 6° 16′ of longitude, and 12° 36′ N. latitude.

*Answer.* γ in Pegasus.

2. On the 15th of June 1826, at noon, the moon's longitude will be $6^{s}$ 22° 24′, and her latitude 3° 24′ S.: find her place on the globe.

3. What stars have the following latitudes and longitudes?

| Latitudes. | Longitudes. | Latitudes. | Longitudes. |
|---|---|---|---|
| 12° 35′ S. | $1^{s}$ 11° 25′ | 39° 33′ S. | $3^{s}$ 11° 13′ |
| 5 29 S. | 2 6 53 | 10 4 N. | 3 17 21 |
| 31 8 S. | 2 13 56 | 0 27 N. | 4 26 57 |
| 22 52 N. | 2 18 57 | 44 20 N. | 7 9 22 |
| 16 3 S. | 2 25 51 | 21 6 S. | 11 0 56 |

4. On the 13th of November 1826, at noon, the longitudes and latitudes of the planets will be as follow: required their places on the globe.

| Longitudes. | Latitudes. | Longitudes. | Latitudes. |
|---|---|---|---|
| ☿ $8^{s}$ 8° 11′ | 2° 13′ S. | ♃ $6^{s}$ 6° 24′ | 1° 9′ N. |
| ♀ 5 2 37 | 4 10 S. | ♄ 3 5 33 | 0 59 S. |
| ♂ 9 25 25 | 1 39 S. | ♅ 9 20 56 | 0 29 S. |

## PROBLEM LXIX.

*The day and hour, and the latitude of a place being given, to find what stars are rising, setting, culminating, &c.*

**Rule.** Elevate the pole to the latitude of the place; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour circle to twelve; then, if the time be before noon, turn the globe eastward on its axis till the index has passed over as many hours as the time wants of noon, but, if the time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon: then all the stars on the eastern semi-circle of the horizon will be rising, those on the western semi-circle will be the setting, those under the brass meridian above the horizon will be the culminating, those above the horizon will be visible at the given time and place, those below will be invisible.

If the globe be turned on its axis from east to west, those stars which do not go below the horizon never set at the given place; and those which do not come above the horizon never rise; or, if the given latitude be subtracted from 90 degrees, and circles be described on the globe, parallel to the equinoctial, at a distance from it equal to the degrees in the remainder, they will be the circles of perpetual apparition and occultation.

EXAMPLES. 1. On the 9th of February, when it is nine o'clock in the evening at London, what stars are rising, what stars are setting, and what stars are on the meridian?

*Answer.* Alphacca, in the northern Crown is rising; Arcturus and Mirach, in Boötes, just above the horizon; Sirius on the meridian; Procyon and Castor and Pollux a little east of the meridian. The constellations Orion, Taurus, and Auriga, a little west of the meridian; Markab, in Pegasus, just below the western edge of the horizon, &c.

2. On the 20th of January, at two o'clock in the morning at London, what stars are rising, what stars are setting, and what stars are on the meridian?

*Answer.* Vega in Lyra, the head of the Serpent, Spica Virginis, &. are rising; the head of the Great Bear, the claws of Cancer, &c. on the meridian; the head of Andromeda, the neck of Cetus, and the body of Columba Noachi, &c. are setting.

3. At ten o'clock in the evening at Edinburgh, on the 15th of November, what stars are rising, what stars are setting, and what stars are on the meridian?

4. What stars do not set in the latitude of London, and at what distance from the equinoctial is the circle of perpetual apparition?

5. What stars do not rise to the inhabitants of Edinburgh, and at what distance from the equinoctial is the circle of perpetual occultation?

6. What stars never rise at Otaheite, and what stars never set at Jamaica?

7. How far must a person travel southward from London to lose sight of the Great Bear?

8. What stars are continually above the horizon at the north pole, and what stars are constantly below the horizon thereof?

## PROBLEM LXX.

*The latitude of a place, day of the month, and hour being given, to place the globe in such a manner as to represent the heavens at that time; in order to find out the relative situations and names of the constellations and remarkable stars.*

Rule. Take the globe out into the open air, on a clear star-light night, where the surrounding horizon is uninterrupted by different objects; elevate the pole to the latitude of the place, and set the globe due north and south by a meridian line, or by a mariner's compass, taking care to make a proper allowance for the variation; find the sun's place in the ecliptic, bring it to the brass meridian and set the index of the hour-circle to twelve; then, if the time be after noon, turn the globe westward on its axis, till the index has passed over as many hours as the time is past noon; but, if the time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; fix the globe in this position, then the flat end of a pencil being placed on any star on the globe so as to point towards the centre, the other end will point to that particular star in the heavens.

## PROBLEM LXXI.

*To find when any star, or planet, will rise, come to the meridian, and set at any given place.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve. Then if the star* or planet be *below* the horizon, turn the globe *westward* till the star or planet comes to the eastern part of the horizon, the hours passed over by the index will show the time from noon when it rises; and, by continuing the motion of the globe westward till the star, &c. comes to the meridian, and to the western part of the horizon successively, the hours passed over by the index will show the time of culminating and setting.

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* The latitude and longitude (or the right ascension and declination) of the planet must be taken from an ephemeris, and its place on the globe must be determined by Prob. LXVIII. (or LXVII.)

If the star, &c. be *above* the horizon and *east* of the meridian, find the time of culminating, setting, and rising, in a similar manner. If the star, &c. be *above* the horizon *west* of the meridian, find the time of setting, rising, and culminating, by turning the globe westward on its axis.

**Examples.** 1. At what time will Arcturus rise, come to the meridian, and set, at London, on the 7th of September?

*Answer.* It will rise at seven o'clock in the morning, come to the meridian at three in the afternoon, and set at 11 o'clock at night.

2. On the first of August, 1805, the longitude of Jupiter was 7 signs, 26 degrees, 34 minutes, and his latitude 45 minutes N.; at what time did he rise, culminate, and set, at Greenwich, and whether was he a morning or an evening star?

*Answer.* Jupiter rose at half-past two in the afternoon, came to the meridian at about ten minutes to seven, and set at a quarter past eleven in the evening. Here Jupiter was an evening star, because he set after the sun.

3. At what time does Sirius rise, come to the meridian of London, and set, on the 31st of January?

4. On the first of January, 1825, the longitude of Venus was 10 signs 18 deg. 51 min., and her latitude 1 deg. 48 min. S.; at what time did she rise, culminate, and set, at Paris, and whether was she a morning or an evening star?

5. At what time does Aldebaran rise, come to the meridian, and set at Dublin, on the 25th of November?

6. On the first of February, 1825, the longitude of Mars was eleven signs 9 deg. 59 min., and latitude 0 deg. 53 min. S.; at what time did he rise set, and come to the meridian of Greenwich?

## PROBLEM LXXII.

*To find the amplitude of any star, its oblique ascension and descension, and its diurnal arc for any given day.*

**Rule.** Elevate the pole to the latitude of the place, and bring the given star to the eastern part of the horizon; then the number of degrees between the star and the eastern point of the horizon will be its rising amplitude; and the degree of the equinoctial of the hour-circle to twelve, and turn the globe westward till the given star comes to the western egde of the horizon; the hours passed over by the index will be the star's diurnal arc, or continuance above the horizon. The setting amplitude will be the number of degrees between the star and the western point of the horizon, and the oblique descension will be represented by that degree of the equinoctial which is intersected by the horizon, reckoning from the point Aries.

EXAMPLES. 1. Required the rising and setting amplitude of Sirius, its oblique ascension, oblique descension, and diurnal arc, at London.

*Answer.* The rising amplitude is 27° to the south of the east; setting amplitude 27° south of the west; oblique ascension 120°; oblique descension 77°; and diurnal arc 9 hours 6 minutes.

2. Required the rising and setting amplitude of Aldebaran, its oblique ascension, oblique descension, and diurnal arc, at London.

3. Required the rising and setting amplitude of Arcturus, its oblique ascension, oblique descension, and diurnal arc, at London.

4. Required the rising and setting amplitude of γ Bellatrix, its oblique ascension, oblique descension, and diurnal arc, at London.

## PROBLEM LXXIII.

*The latitude of a place given, to find the time of the year at which any known star rises or sets* ACRONICALLY, *that is, when it rises or sets at sun-setting.*

RULE. Elevate the pole to the latitude of the place, bring the given star to the eastern edge of the horizon, and observe what degree of the ecliptic is intersected by the western edge of the horizon, the day of the month answering to that degree will show the time when the star rises at sun-set, and consequently when it begins to be *visible in the evening*. Turn the globe westward on its axis till the star comes to the western edge of the horizon, and observe what degree of the ecliptic is intersected by the horizon as before: the day of the month answering to that degree will show the time when the star sets with the sun, or when it *ceases to appear in the evening*.

EXAMPLES. 1. At what time does Arcturus rise acronically at

Ascra* in Bœotia, the birth-place of Hesiod; the latitude of Ascra, according to Ptolemy, being 37° 45′ N.?

*Answer.* When Arcturus is at the eastern part of the horizon, the eleventh degree of Aries will be at the western part answering to the first of April,† the time when Arcturus rises acronically: and it will set acronically on the 30th of November.

2. At what time of the year does Aldebaran rise acronically at Athens, in 38° N. latitude; and at what time of the year does it set acronically?

3. On what day of the year does γ in the extremity of the wing of Pegasus rise acronically at London; and on what day of the year does it set acronically?

4. On what day of the year does ε in the right foot of Lepus rise acronically at London; and on what day of the year does it set acronically?

## PROBLEM LXXIV.

*The latitude of a place given, to find the time of the year at which any known star rises or sets* COSMICALLY, *that is, when it rises or sets at sun-rising.*

Rule. Elevate the pole to the latitude of the place, bring the given star to the eastern edge of the horizon, and observe what sign and degree of the ecliptic are intersected by the horizon; the month and day of the month, answering to that sign and degree, will show the time when the star rises with the sun. Turn the globe westward on its axis till the star comes to the western

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[*] See page 37.

[†] Hence Arcturus now rises acronically in latitude 37° 45′ N. about 100 days after the winter solstice. Hesiod, in his *Opera and Dies* lib. ii. verse 185, says:

> When from the solstice sixty wintry days
> Their turns have finished, mark, with glitt'ring rays,
> From Ocean's sacred flood *Arcturus* rise,
> Then first to gild the dusky evening skies.

Here is a difference of 40 days in the acronical rising of this star (supposing Hesiod to be correct) between the time of Hesiod and the present time; and as a day answers to about 59′ of the ecliptic (see the note page 36,) 40 days will answer to 39 degrees; consequently, the winter solstice in the time of Hesiod was in the 9th degree of Aquarius. Now, the recession of the equinoxes is about 50¼″ in a year: hence 50¼″ : 1 year : : 39° : 2794 years since the time of Hesiod; so that he lived 990 years before Christ, by this mode of reckoning. Lempriere, in his Classical Dictionary, says Hesiod lived 907 years before Christ.

edge of the horizon, and observe what sign and degree of the ecliptic are intersected by the eastern edge, as before; these will point out on the horizon the time when the star sets at sun-rising.

Examples. 1. At what time of the year do the Pleiades set cosmically at Miletus in Ionia, the birth-place of Thales; and at what time of the year do they rise cosmically; the latitude of Miletus, according to Ptolemy, being 37° north?

*Answer.* The Pleiades rise with the sun on the 10th of May, and they set at the time of sun-rising on the 22d of November.*

2. At what time of the year does Sirius rise with the sun at London; and at what time of the year will Sirius set when the sun rises?

3. At what time of the year does Menkar, in the jaw of Cetus, rise with the sun, and at what time does it set at sun-rising at London?

4. At what time of the year does Procyon, in the Little Dog, set when the sun rises at London, and at what time of the year does it rise with the sun?

## PROBLEM LXXV.

### *To find the time of the year when any given star rises or sets* HELICALLY.†

Rule. The heliacal rising and setting of the stars will vary according to their different degrees of magnitude and brilliancy; for it is evident that the brighter a star is when above the horizon, the less the sun will be depressed below the horizon when that star first becomes visible. According to Ptolemy, stars of the *first* magnitude are seen rising and setting when the sun is twelve degrees below the horizon; stars of the *second* magnitude require the sun's depression to be thirteen degrees; stars of the *third* magnitude fourteen degrees, and so on, reckoning one degree for each magnitude. This being premised:

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* Pliny says (Nat. Hist. lib. xviii. cap. 25.) that Thales determined the cosmical setting of the Pleiades to be twenty-five days after the autumnal equinox. Supposing this observation to be made at Miletus, there will be a difference of thirty-five days in the cosmical setting of this star since the time of Thales; and, as a day answers to about 59′ of the ecliptic, these days will make about 34° 25′; consequently, in the time of Thales, the autumnal equinoctial colure passed through 4° 25′ of Scorpio; and, as before, 50¼″ : 1 year : : 34° 25′ : 2465 years since the time of Thales, so that Thales lived (2465—1804) 661 years before the birth of Christ. According to Sir. I. Newton's Chronology, Thales flourished 596 years before Christ. Thales was well skilled in geometry, astronomy, and philosophy; he measured the height and extent of the Pyramids of Egypt, was the first who calculated with accuracy a solar eclipse; he discovered the solstices and equinoxes, divided the heavens into five zones, and recommended the division of the year into 365 days. Miletus was situated in Asia Minor, south of Ephesus, and south-east of the island of Samos.

† See Definition 90., page 45.

To SOLVE THE PROBLEM. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian over that latitude; bring the given star to the eastern edge of the horizon, and move the quadrant of altitude till it intersects the ecliptic twelve degrees below the horizon, if the star be of the first magnitude; thirteen degrees, if the star be of the second magnitude; fourteen degrees, if it be of the third magnitude, &c.: the point of the ecliptic, cut by the quadrant, will show the day of the month, on the horizon, when the star rises heliacally. Bring the given star to the western edge of the horizon, and move the quadrant of altitude till it intersects the ecliptic below the western edge of the horizon, in a similar manner as before; the point of the ecliptic cut by the quadrant will show the day of the month, on the horizon, when the star sets heliacally.

EXAMPLES. 1. At what time does β Tauri, or the bright star in the Bull's Horn, of the second magnitude, rise and set heliacally at Rome?

*Answer.* The quadrant will intersect the third of Cancer 13° below the eastern horizon, answering to the 24th of June; and the 7th of Gemini 13° below the western horizon, answering to the 28th of May.

2. At what time of the year does Sirius, or the Dog Star, rise heliacally at Alexandria in Egypt; and at what time does it set heliacally at Alexandria in Egypt; and at what time does it set heliacally at the same place?

*Answer.* The latitude of Alexandria is 31 deg. 13 min. north; the quadrant will intersect the 12th of Leo, 12° below the eastern horizon, answering to the 4th of August[*]; and the 2d of Gemini, 12 degrees below the western horizon, answering to the 23d of May.

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[*] The ancients reckoned the beginning of the *Dog Days* from the heliacal rising of Sirius, and their continuance to be about 40 days. Hesiod informs us that the hottest season of the year (*Dog Days*) ended about 50 days after the summer solstice. We have determined in the note of Example 1. Problem LXXIII. (though perhaps not very accurately), that the winter solstice, in the time of Hesiod, was in the 9th degree of Aquarius; consequently, the summer solstice was in the 9th degree of Leo: now, it appears from above, that Sirius rises heliacally at Alexandria when the sun is in the 12th degree of Leo; and, as a degree nearly answers to a day, Sirius rose heliacally in the time of Hesiod, about four days after the

3. At what time of the year does Arcturus rise heliacally at Jerusalem, and at what time does it set heliacally?

4. At what time of the year does Cor Hydræ rise and set heliacally at London?

5. At what time of the year does Procyon rise and set heliacally at London?

6. If the precession of the equinoxes be 50¼ seconds in a year, how many years will elapse, from 1825 before Sirius, the Dog Star, will rise heliacally at Christmas, at Cairo in Egypt? When this period happens, Sirius will perhaps no longer be accused of bringing sultry weather.

## PROBLEM LXXVI.

*The latitude of a place and day of the month being given, to find all those stars that rise and set* ACRONICALLY, COSMICALLY, *and* HELIACALLY.*

RULE. Elevate the pole so many degrees above the horizon as are equal to the latitude of the given place. Then,

1. *For the acronical rising and setting*, find the sun's place in the ecliptic, and bring it to the *western* edge of the horizon, and

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summer solstice; and if the Dog Days continued forty days, they ended about fory-four days after the summer solstice. The Dog Days in our almanacs begin on the third of July, which is twelve days after the summer solstice, and end on the 11th of August, which is fifty-one days after the summer solstice; and their continuance is 39 days. Hence it is plain, that the Dog Days of the moderns have no reference whatever to the rising of Sirius, for this star rises heliacally at London on the 25th of August, and, as well as the rest of the stars, varies in its rising and setting according to the variation of the latitudes of places, and therefore it could have no influence whatever on the temperature of the atmosphere; yet, as the Dog Star rose heliacally at the commencement of the hottest season in Egypt, Greece, &c. in the earlier ages of the world, it was very natural for the ancients to imagine that the heat, &c. was the effect of this star. A few years ago, the Dog Days in our almanacs began at the *cosmical* rising of Procyon, viz. on the 30th of July, and continued to the 7th of September; but they are now, very properly, altered, and made not to depend on the variable rising of any particular star, but on the summer solstice.

* This problem is the reverse of the three preceding problems. Their principal use is to illustrate several passages in the ancient writers, such as Hesiod, Virgil, Columella, Ovid, Pliny, &c. See definition 64., page 37. The knowledge of these poetical risings and settings of the stars was held in great esteem among the ancients, and was very useful to them in adjusting the times set apart for their religious and civil duties, and for marking the seasons proper for the several parts of

all the stars along the eastern edge of the horizon will rise acronically, while those along the western edge will set acronically.

2. *For the cosmical rising and setting*, bring the sun's place to the *eastern* edge of the horizon, and all the stars along that edge of the horizon will rise cosmically, while those along the western edge will set cosmically.

3. *For the heliacal rising and setting*, screw the quadrant of altitude over the latitude, turn the globe eastward on its axis till the sun's place cuts the quadrant twelve degrees below the horizon; then all the stars of the first magnitude, along the eastern edge of the horizon, will rise heliacally; and, by continuing the motion of the globe eastward till the sun's place interects the quadrant in 13, 14, 15, &c. degrees below the horizon, you will find all the stars of the *second, third, fourth*, &c. magnitudes, which rise heliacally on that day. By turning the globe westward on its axis, in a similar manner, and bringing the quadrant to the western egde of the horizon, you will find all the stars that set heliacally.

EXAMPLES. 1. What stars rise and set cosmically at Edinburgh, on the 11th of June?

*Answer.* The bright star in Castor, Aldebaran in Taurus, Fomalhaut in the southern Fish, &c. rise cosmically; those stars in the body of Leo Minor, the arm of Virgo, the right foot of Boötes, part of the Centaur, &c. set cosmically.

2. What stars rise and set acronically at Drontheim in Norway, latitude 63° 26′ N. on the 18th May?

*Answer.* Altair in the Eagle, the head of the Dolphin, &c. rise acronically; and Aldebaran in Taurus, Betelgeux in Orion, &c. set acronically.

3. What star of the first magnitude rises heliacally at London, on the 7th of October?

4. What star of the first magnitude sets heliacally at London, on the 5th of May?

5. What stars rise and set acronically at London, on the 26th of September?

6. What stars rise and set cosmically at London, on the 23d of March?

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husbandry; for the knowlegde of which the ancients had of the motions of the heavenly bodies was not sufficient to adjust the true length of the year; and, as the returns of the seasons depends upon the approach of the sun to the tropical and equinoctial points, so they made use of these risings and settings to determine the commencement of the different seasons, the time of the overflowing of the Nile, &c. The knowledge which the moderns have acquired of the motions of the heavenly bodies renders such observations as the ancients attended to in a great measure useless; and, instead of watching the rising and setting of particular stars for any remarkable season, they can sit by the fire-side and consult an almanac.

## PROBLEM LXXVII.

### *To illustrate the precession of the equinoxes.*

Observations. All the stars in the different constellations continually increase in longitude ; consequently either the whole starry heavens have a slow motion from west to east, or the equinoctial points have a slow motion from east to west. In the time of Meton*, the first star in the constellation Aries, now marked β, passed through the vernal equinox, whereas it is now upwards of 30† degrees to the eastward of it.

Illustration. Elevate the north pole 90 degrees above the horizon, then will the equinoctial coincide with the horizon ; bring the pole‡ of the ecliptic to that part of the brass meridian which is numbered from the north pole towards the equinoctial, and make a mark upon the brass meridian above it ; let this mark be considered as the pole of the world, let the equinoctial represent the ecliptic, and let the ecliptic be considered as the equinoctial ; then count 38½ degrees, the complement of the latitude of London, from this pole upwards, and mark where the reckoning ends, which will be at 75° on the brass meridian, from the southern point of the horizon ; this mark will stand over the latitude of London.

Now turn the globe gently on its axis from east to west, and the equinoctial points will move the same way, while, at the same time, the pole of the world|| will describe a circle round the pole of the ecliptic§ of 46° 56′ in diameter ; this circle will be completed

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* Meton was a famous mathematician of Athens, who flourished about 432 years before Christ. In a book called *Enneadecaterides* or cycle of 19 years, he endeavoured to adjust the course of the sun and of the moon ; and attempted to show that the solar and lunar years could regularly begin from the same point in the heavens.

† If the precession of the equinoxes be 50¼′ in a year, and if the equinoctial colure passed through β Arietis, 430 years before Christ, the longitude of this star ought now, (1804) to be 31° 10′ 58″ ; for, 1 year : 50¼″ : : 2234 years (=430 + 1804) : 31° 10′ 58″ ; and this longitude is not far from the truth.

‡ The pole of the ecliptic is that point on the globe, in the arctic circle, where the circular lines meet.

|| Let it be remembered that the pole of the ecliptic on the globe here represents the pole of the world.

§ Take notice, that the extremity of the globe's axis here represents the pole of the ecliptic.

in a Platonic year*, consisting of 25,791 years, at the rate of 50¼ seconds in a year, and the pole of the heavens will vary its situation a small matter every year. When 12,895½ years, being half the Platonic year, are completed, (which may be known by turning the globe half round, or till the point Aries coincides with the eastern point of the horizon,) that point of the heavens which is now 8½ degrees south of the zenith of London, will be the north pole†, as may be seen by referring to the mark which was made over 75 degrees on the meridian.

## PROBLEM LXXVIII.

*To find the distances of the stars from each other in degrees.*

Rule. Lay the quadrant of altitude over any two stars, so that the division marked o may be on one of the stars; the degrees between them will show their distance, or the angle which these stars subtend, as seen by a spectator on the earth.

Examples. 1. What is the distance between Vega in Lyra, and altair in the Eagle.

*Answer.* 34 degrees.

2. Required the distance between β in the Bull's Horn, and γ Bellatrix in Orion's shoulder.

3. What is the distance between β in Pollux, and α in Procyon?

4. What is the distance between η, the brightest of the Pleiades, and β in the Great Dog's Foot?

5. What is the distance between ε in Orion's Girdle, and ζ in Cetus?

6. What is the distance between Arcturus in Boötes, and β in the right shoulder of Serpentarius?

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* A Platonic year is a period of time determined by the revolution of the equinoxes; this period being once completed, the ancients were of opinion that the world was to begin anew, and the same series of things to return over again. See the 64th Definition, page 37.

† See page 134.

## PROBLEM LXXIX.

*To find what stars lie in or near the moon's path, or what stars the moon can eclipse, or make a near approach to.*

Rule. Find the moon's longitude and latitude, or her right ascension and declination, in an ephemeris, for several days, and mark the moon's places on the globe (as directed in Problems LXVIII. or LXVII.); then by laying a thread, or the quadrant of altitude, over these places, you will see nearly the moon's path,* and consequently what stars lie in her way.

Examples. 1. What stars were in, or near, the moon's path, on the 10th, 11th, 13th, and 16th of December, 1805?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 10th, | ●'s longitude | ♌ 20° | 12′ | latitude | 3° | 34′ | S. |
| 11th, | - | ♍ 4 | 22 | - - | 4 | 25 | S. |
| 13th, | - | ♎ 1 | 39 | - - | 5 | 15 | S. |
| 16th, | - | ♏ 10 | 11 | - - | 4 | 26 | S. |

*Answer.* The stars will be found to be Cor Leonis or Regulus, Spica Virginis, *a* in Libra, &c. See page 47, White's Ephemeris.

2. On the 1st, 2d, 3d, 4th, and 5th of August, 1826, what stars will lie near the moon's way?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1st, | ●'s right ascension | 108° | 14 | declination | 18° | 40′ | N. |
| 2d, | - - | 121 | 25 | - - | 15 | 51 | N. |
| 3d, | - - | 134 | 29 | - - | 12 | 10 | N. |
| 4th, | - - | 147 | 24 | - - | 7 | 49 | N. |
| 5th, | - - | 160 | 16 | - - | 3 | 0 | N. |

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* The situation of the moon's orbit for any particular day may be found thus: find the place of the moon's ascending node in the Ephemeris, mark that place and its antipodes (being the ascending node) on the globe; half the way between these points make marks 5° 20′ on the north and south side of the ecliptic, viz. let the northern mark be between the ascending and descending node, and the southern between the descending and ascending node; a thread tied round these four points will show the position of the moon's orbit.

## PROBLEM LXXX.

*Given the latitude of the place and the day of the month, to find what planets will be above the horizon after sun-setting.*

**Rule.** Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the sun's place in the ecliptic, and bring it to the western part of the horizon, or to ten or twelve degrees below; then look in the Ephemeris for that day and month, and you will find what planets are above the horizon, such planets will be fit for observation on that night.

**Examples.** 1. Were any of the planets visible after the sun had descended ten degrees* below the horizon of London, on the first of December, 1805? Their longitudes being as follow:

| | | | | |
|---|---|---|---|---|
| ☿ | 8s 22° 30 | ♃ | 8s 15 27′ | ●'s longitude at |
| ♀ | 9 23 40 | ♄ | 6 24 50 | midnight 0s 9° |
| ♂ | 8 25 21 | ♅ | 6 24 5 | |

*Answer.* Venus and the moon were visible.

2. What planets will be above the horizon of London when the sun has descended ten degrees below, on the first of January, 1826? Their longitudes being as follow:

| | | | | |
|---|---|---|---|---|
| ☿ | 9s 9° 25′ | ♃ | 5s 14° 27°′ | ●'s longitude at |
| ♀ | 8 24 13 | ♄ | 2 16 44 | midnight 6s 17° 31′. |
| ♂ | 6 22 19 | ♅ | 9 19 29 | |

## PROBLEM LXXXI.

*Given the latitude of the place, day of the month, and hour of the night or morning, to find what planets will be visible at that hour.*

**Rule.** Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve: then, if the given time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; but if the given time be past noon, turn the globe westward on its axis till the index has passed over as many hours as the time is past noon; let the globe rest in this position, and look in the Ephemeris for the longitudes* of the planets, and, if any of them be in the signs which are above the horizon, such planet will be visible.

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* The planets are not visible till the sun is a certain number of degrees below the horizon, and these degrees are variable according to the brightness of the planets. Mercury becomes visible when the sun is about ten degrees below the horizon; Venus when the sun's depression is 5 degrees; Mars 11° 30′; Jupiter 10°; [redacted]

**Examples.** 1. On the first of December, 1805, the longitudes of the planets, by an ephemeris, were as follow: were any of them visible at London at five o'clock in the morning?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ☿ | 8s | 22° | 30′ | ♃ | 8s | 15° | 27′ |
| ♀ | 9 | 22 | 40 | ♄ | 6 | 24 | 50 |
| ♂ | 8 | 25 | 21 | ♅ | 6 | 24 | 5 |

☽'s longitude at midnight 0s 9° 15′.

*Answer.* Saturn and the Georgium Sidus were visible, and both nearly in the same point of the heavens, near the eastern horizon, Saturn was a little to the north of the Georgian.

2. On the first of June, 1826, the longitudes of the planets in the fourth page of the Nautical Almanc are as follow: will any of them be visible at London at ten o'clock in the evening?

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ☿ | 1s | 18° | 4′ | ♃ | 5s | 5° | 52′ |
| ♀ | 3 | 1 | 45 | ♄ | 2 | 23 | 27 |
| ♂ | 7 | 6 | 2 | ♅ | 9 | 23 | 38 |

☽'s longitude at midnight 0s 30° 5′.

## PROBLEM LXXXII.

*The latitude of the place and day of the month being given, to find how long Venus rises before the sun when she is a morning star, and how long she sets after the sun when she is an evening star.*

**Rule.** Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the latitude and longitude of Venus in an ephemeris, and mark her place on the globe; find the sun's place in the ecliptic, and bring it to the brass meridian: then, if the place of Venus be to the right hand of the meridian, she is an evening star; if to the left hand, she is a morning star.

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* It is not necessary to give the latitudes of the planets in this problem; for if the signs and degrees of the ecliptic in which their longitudes are situated be above the horizon, the planets will likewise be above the horizon.

*When Venus is an evening star.* Bring the sun's place to the western edge of the horizon, and set the index of the hour-circle to twelve; turn the globe westward on its axis till Venus coincides with the western edge of the horizon; and the hours passed over by the index will show how long Venus sets after the sun.

*When Venus is a morning star.* Bring the sun's place to the eastern edge of the horizon, and set the index of the hour-circle to twelve; turn the globe eastward on its axis till Venus comes to the eastern edge of the horizon, and the hours passed over by the index will show how long Venus rises before the sun.

NOTE. *The same rule will serve for Jupiter by marking his place instead of that of Venus.*

EXAMPLES. 1. On the first of March 1805, the longitude of Venus was 10 signs, 18 deg. 14 min., or 18 deg. 14 min. in Aquarius, latitude 0 deg. 52 min. south: was she a morning or an evening star? If a morning star, how long did she rise before the sun at London; if an evening star, how long did she shine after the sun set?

*Answer.* Venus was a morning star, and rose three quarters of an hour before the sun.

2. On the 25th of October, 1805, the longitude of Jupiter was 8 signs, 7 deg. 26 min., or 7 deg. 26 min. in Sagittarius, latitude 0 deg. 29 min. north: whether was he a morning or an evening star? If a morning star, how long did he rise before the sun at London? If an evening star, how long did he shine after the sun set?

*Answer.* Jupiter was an evening star, and set 1 hour and 20 minutes after the sun.

3. On the first of January, 1826, the longitude of Venus will be 8 signs, 24 deg. 13 min., latitude 0 deg. 21 min. north; will she be an evening or a morning star? If she be a morning star, how long will she rise before the sun at London? If an evening star, how long will she shine after the sun sets?

4. On the 7th of July, 1826, the longitude of Jupiter will be 5 signs, 10 deg. 27 min., latitude 1 deg. 8 min. north; will he be a morning or an evening star? If he be a morning star, how long will he rise before the sun? If an evening star, how long will he shine after the sun sets?

## PROBLEM LXXXIII.

*The latitude of a place and day of the month* being given, to find the meridian altitude of any star or planet.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; then,

*For a star.* Bring the given star to that part of the brass meridian, which is numbered from the equinoctial towards the poles; the degrees on the meridian contained between the star and the horizon will be the altitude required.

*For the moon or a planet.* Look in an ephemeris for the planet's latitude and longitude, or for its right ascension and declination, for the given month and day, and mark its place on the globe, (as in Prob. LXVIII. or LXVII.); bring the planet's place to the brass meridian; and the number of degrees between that place and the horizon will be the altitude.

Examples. 1. What is the meridian altitude of Aldebaran in Taurus, at London?

*Answer.* 54° 36′.

2. What is the meridian altitude of Arcturus in Boötes, at London?

3. On the first of February 1826, the longitude of Jupiter will be 5 signs, 12 deg. 45 min., and latitude 1 deg. 21 min. north; what will his meridian altitude be at London?

4. On the first of November 1826, the longitude of Saturn will be 3 signs 5 deg. 58 min. and latitude 0 deg. 59 min. south; what will his meridian altitude be at London?

5. On the 16th of May 1826, at the time of the moon's passage over the meridian of Greenwich, her right ascension is 169° 48′

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* The meridian altitudes of the stars on the globe, in the same latitude, are invariable; therefore, when the meridian altitude of a star is sought, the day of the month need not be attended to.

and declination 1° 4′ south; required her meridian altitude at Greenwich?*

6. On the 11th of December 1826, the moon will pass over the meridian of Greenwich at 3 minutes past 10 o'clock in the evening; required her meridian altitude?

The ●'s right ascension at noon being 44° 7′, declination 17° 27′ N.
Do. at midnight - - - 50 14 - - 18 32 N.

## PROBLEM LXXXIV.

*To find all those places on the earth to which the moon will be nearly vertical on any given day.*

**Rule.** Look in an ephemeris for the moon's latitude and longitude for the given day, and mark her place on the globe (as in Prob. LXVIII.); bring this place to that part of the brass meridian which is numbered from the equinoctial towards the poles, and observe the degree above it; for all places on the earth having that latitude will have the moon vertical (or nearly so) when she comes to their respective meridians.

**Or:** Take the moon's declination from page VI. of the Nautical Almanac, and mark whether it be north or south, then by the terrestrial globe, or by a map, find all places having the same number of degrees of latitude as are contained in the moon's declination, and those will be the places to which the moon will be successively vertical on the given day. If the moon's declination be north, the places will be in north latitude; if the moon's declination be south, they will be in south latitude.

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* By the Nautical Almanac, the moon will pass over the meridian at 38 minutes past 7 o'clock in the evening, on the 16th of May 1826.

169° 48′ ●'s right ascension at midnight—Declination 1° 4′ S.
163 16 do. at - - - noon - ditto - 1 30 N.
6 32 increase in 12 hours from noon - - 2 34

12 h. : 6° 32′ : : 7 h. 38′ : 4° 9′; hence 163° 16′ + 4° 9′ = 167° 25′ the moon's right ascension at 38 minutes past 7.

12 h. : 2° 34′ : : 7 h. 38′ : 1° 37′; hence 1° 30′—1° 37′ = 0° 7′ S. the moon's declination at 38 minutes past 7.

The places of the planets may be taken out of the Ephemeris for noon without sensible error, because their declinations vary less than that of the moon.

The moon will have the greatest and least meridian altitude to all the inhabitants north of the equator, when her ascending node is in Aries; for her orbit making an angle of 5⅓° with the ecliptic, her greatest altitude will be 5⅓ more than the greatest meridional altitude of the sun, and her least meridional altitude 5⅓° less than that of the sun. The greatest altitude of the sun at London is 62°; the moon's greatest altitude is therefore 67° 20′. The least meridional altitude of the sun at London is 15°; the least meridional altitude of the moon is therefore 9° 40′.

Examples. 1. On the 15th of October, 1805, the moon's longitude at midnight was 3 signs, 29 deg. 14 min., and her latitude 1 deg. 35 min. south; over what places did she pass nearly vertical?

*Answer.* From the moon's latitude and longitude being given, her declination may be found by the globe to be about 19° north. The moon was vertical at Porto Rico, St. Domingo, the north of Jamaica, Owhyhee, &c.

2. On the 9th of September, 1826, the moon's longitude at midnight will be 8 signs, 30 deg., and her latitude 2 deg. 48 min. north; over what places on the earth will she pass nearly vertical?

3. What is the greatest north declination which the moon can possibly have, and to what places will she be then vertical?

4. What is the greatest south declination which the moon can possibly have, and to what places will she be then vertical?

## PROBLEM LXXXV.

### *Given the latitude of a place, day of the month, and the altitude of a star, to find the hour of the night, and the star's azimuth.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude: find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve; bring the lower end of the quadrant of altitude to that side of the meridian* on which the star was situated when observed; turn the globe *westward* till the centre of the star cuts the given altitude on the quadrant; count the hours which the index has passed over, and they will show the time from noon when the star has the given altitude: the quadrant will intersect the horizon in the required azimuth.

Examples. 1. At London, on the 28th of December, the star

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* It is necessary to know on which side of the meridian the star is at the time of observation, because it will have the same altitude on both sides of it. Any star may be taken at pleasure, but it is best to take one not too near the meridian, because for some time before the star comes to the meridian, and after it has passed it, the altitude varies very little.

Deneb in the Lion's tail, marked β, was observed to be 40° above the horizon, and east of the meridian; what hour was it, and what was the star's azimuth?

*Answer.* By bringing the sun's place to the meridian, and turning the globe westward on its axis till the star cuts 40 degrees of the quadrant *east of the meridian*, the index will have passed over 14 hours; consequently, the star has 40 degrees of altitude east of the meridian, 14 hours from noon or at two o'clock in the morning. Its azimuth will be 62½ degrees from the south towards the east.

2. At London, on the 28th of December, the star β, in the Lion's tail, was observed to be westward of the meridian, and to have 40 degrees of altitude: what hour was it, and what was the star's azimuth?

*Answer.* By turning the globe westward on its axis till the star cuts 40 degrees of the quadrant *west of the meridian*, the index will have passed over 20 hours; consequently, the star has 40 degrees of altitude west of the meridian, 20 hours from noon, or at eight o'clock in the morning. Its azimuth will be 62½° from the south towards the west.

3. At London, on the 1st of September, the altitude of Benetnach in Ursa Major, marked η, was observed to be 36 degrees above the horizon, and west of the meridian; what hour was it, and what was the star's azimuth?

4. On the 21st of December the altitude of Sirius, when west of the meridian at London, was observed to be 8 degrees above the horizon; what hour was it, and what was the star's azimuth?

5. On the 12th of August, Menkar in the Whale's jaw, marked *a*, was observed to be 37 degrees above the horizon of London, and eastward of the meridian; what hour was it, and what was the star's azimuth?

## PROBLEM LXXXVI.

*Given the latitude of a place, day of the month, and hour of the day, to find the altitude of any star, and its azimuth.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve; then, if the given time be before noon, turn the globe eastward on its axis till the index has passed over as many hours as the time wants of noon; if the time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon: let the globe rest in this position, and move the quadrant of altitude till its graduated edge coincides with the centre of the given star; the degrees on the quadrant, from the horizon to the star, will be the altitude; and the distance from the north and south point of the horizon to the quadrant, counted on the horizon, will be the azimuth from the north and south.

Examples. 1. What are the altitude and azimuth of Capella at Rome, when it is five o'clock in the morning on the second of December?

*Answer.* The altitude is 41° 58′, and the azimuth 60° 50′ from the north towards the west.

2. Required the altitude and azimuth of Altair in Aquila on the 6th of October, at nine o'clock in the evening, at London?

3. On what point of the compass does the star Aldebaran bear at the Cape of Good Hope, on the 5th of March, at a quarter past eight o'clock in the evening; and what is its altitude?

4. Required the altitude and azimuth of Acyone in the Pleiades marked η, on the 21st of December, at four o'clock in the morning at London?

## PROBLEM LXXXVII.

*Given the latitude of the place, day of the month, and azimuth of a star, to find the hour of the night and the star's altitude.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place upon the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve; bring the lower end of the quadrant of altitude to coincide with the given azimuth on the horizon, and hold it in that position; turn the globe westward till the given star comes to the graduated edge of the quadrant, and the hours passed over by the index will be the time from noon; the degrees on the quadrant, reckoning from the horizon to the star, will be the altitude.

Examples. 1. At London, on the 28th of December, the azimuth of Deneb in the Lion's tail marked β, was 62½° from the south towards the west, what hour was it, and what was the star's altitude?

*Answer.* By turning the globe westward on its axis, the index will pass over 20 hours before the star intersects the quadrant; therefore the time will be 20 hours from noon, or eight o'clock in the morning; and the star's altitude will be 40 degrees.

2. At London, on the 5th of May, the azimuth of Cor Leonis, or Regulus, marked α, was 74° from the south towards the west; required the star's altitude, and the hour of the night.

3. On the 8th of October, the azimuth of the star marked β, in the shoulder of Auriga, was 50° from the north towards the east; required its altitude at London, and the hour of the night.

4. On the 10th of September, the azimuth of the star marked ι, in the Dolphin, was 20° from the south towards the east; required its altitude at London, and the hour of the night.

## PROBLEM LXXXVIII.

*Two stars being given, the one on the meridian, and the other on the east or west part of the horizon, to find the latitude of the place.*

Rule. Bring the star which was observed to be on the meridian, to the brass meridian; keep the globe from turning on its axis, and elevate or depress the pole till the other star comes to the eastern or western part of the horizon; then the degrees from the elevated pole to the horizon will be the latitude.

Examples. 1. When the two pointers* of the Great Bear, marked α and β, or Dubhe and β, were on the meridian, I observed Vega in Lyra to be rising; required the latitude.

*Answer.* 27° north.

2. When Arcturus in Boötes was on the meridian, Altair in the Eagle was rising; required the latitude.

3. When the star marked β in Gemini was on the meridian, ε in the shoulder of Andromeda was setting; required the latitude.

4. In what latitude are α and β, or Sirius and β in Canis Major rising, when Algenib, or α, in Perseus, is on the meridian?

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* These two stars are called the pointers, because a line drawn through them, points to the *polar star* in Ursa Minor. See page 131.

## PROBLEM LXXXIX.

*The latitude of the place, the day of the month, and two stars that have the same azimuth,* being given, to find the hour of the night.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve: turn the globe on its axis from east to west till the two given stars coincide with the graduated edge of the quadrant of altitude; the hours passed over by the index will show the time from noon; and the common azimuth of the two stars will be found on the horizon.

Examples. 1. At what hour, at London, on the first of May, will Altair in the Eagle, and Vega in the Harp, have the same azimuth, and what will that azimuth be?

*Answer.* By bringing the sun's place to the meridian, &c. and turning the globe westward, the index will pass over 15 hours before the stars coincide with the quadrant: hence they will have the same azimuth at 15 hours from noon, or at three o'clock in the morning; and the azimuth will be 42½° from the south towards the east.

2. On the 10th of September, what is the hour at London, when Deneb in Cygnus, and Markab in Pegasus, have the same azimuth, and what is the azimuth?

3. At what hour on the 15th of April will Arcturus and Spica Virginis have the same azimuth at London, and what will that azimuth be?

4. On the 20th of February, what is the hour at Edinburgh when Capella and the Pleiades have the same azimuth, and what is the azimuth?

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* To find what stars have the same azimuth.—Let a smooth rectangular board of about a foot in breadth, and three feet high (or of any height you please), be fixed perpendicularly upon a stand; draw a straight line through the middle of the board, parallel to the sides: fix a pin in the upper part of this line, and make a hole in the board at the lower part of the line; hang a thread with a plummet fixed to it upon the pin, and let the ball of the plummet move freely in the hole made in the lower part of the board: set this board upon a table in a window, or in the open air, and wait till the plummet ceases to vibrate: then look along the face of the board, and those stars which are partly hid from your view by the thread will have the same azimuth.

5. On the 21st of December, what is the hour at Dublin when *α* or Algenib in Perseus, and *β* in the Bull's Horn, have the same azimuth, and what is the azimuth?

## PROBLEM XC.

*The latitude of the place, the day of the month, and two stars that have the same altitude, being given, to find the hour of the night.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve, turn the globe on its axis from east to west till the two given stars coincide with the given altitude on the graduated edge of the quadrant; the hours passed over by the index will be the time from noon when the two stars have that altitude.

Examples. 1. At what hour at London, on the second of September, will Markab in Pegasus, and *α* in the head of Andromeda, have each 30° of altitude?

*Answer.* At a quarter past eight in the evening.

2. At what hour at London, on the 5th of January, will *α*, Menkar, in the Whale's jaw, and *α*, Aldebaran, in Taurus, have each 35° of altitude?

3. At what hour at Edinburgh, on the 10th of November, will *α*, Altair in the body of the Eagle, and *ζ*, in the tail of the Eagle, have each 35° of altitude?

4. At what hour at Dublin, on the 15th of May, will *η*, Benetnach in the Great Bear's tail, and *γ*, in the shoulder of Boötes, have 56° of altitude?

## PROBLEM XCI.

*The altitudes of two stars having the same azimuth, and that azimuth being given, to find the latitude of the place.*

Rule. Place the graduated edge of the quadrant of altitude over the two stars, so that each star may be exactly under its given altitude on the quadrant; hold the quadrant in this position, and elevate or depress the pole till the division marked o, on the lower end of the quadrant, coincides with the given azimuth on the horizon: when this is effected, the elevation of the pole will be the latitude.

Examples. 1. The altitude of Arcturus was observed to be 40 deg., and that of Cor. Caroli 68 deg.; their common azimuth at the same time was 71 deg. from the south towards the east; required the latitude.

*Answer.* 51½ deg. north.

2. The altitude of ε in Castor was observed to be 40 deg., and that of β in Procyon 20 deg.; their common azimuth at the same time was 73½ deg. from the south towards the east; required the latitude.

3. The altitude of α, Dubhe, was observed to be 40 deg., and that of γ in the back of the Great Bear 29½ deg., their common azimuth at the same time was 30 deg. from the north towards the east; required the latitude.

4. The altitude of Vega, or α in Lyra, was observed to be 70 deg., and that of α in the head of Hercules 39½ deg., their common azimuth at the same time was 60 deg. from the south towards the west; required the latitude.

## PROBLEM XCII.

### *The day of the month being given, and the hour when any known star rises or sets, to find the latitude of the place.*

Rule. Find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12; then, if the given time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; but if the given time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon; elevate or depress the pole till the centre of the given star coincides with the horizon; then the elevation of the pole will show the latitude.

Examples. 1. In what latitude does ε, Mirach, in Boötes, rise at half past twelve o'clock at night, on the tenth of December?

*Answer.* 51½ deg. north.

2. In what latitude does Cor Leonis, or Regulus, rise at 10 o'clock at night, on the 21st of January?

3. In what latitude does β, Rigel in Orion, set at 4 o'clock in the morning, on the twenty-first of December?

4. In what latitude does β, Capricornus, set at eleven o'clock at night on the tenth of October?

## PROBLEM XCIII.

### *To find on what day of the year any given star passes the meridian at any given hour.*

Rule. Bring the given star to the brass meridian, and set the index to 12; then, if the given time be before noon*, turn the globe westward till the index has passed over as many hours as the time wants of noon; but, if the given time be past noon, turn the globe eastward till the index has passed over as many hours as the time is past noon; observe that degree of the ecliptic which is intersected by the graduated edge of the brass meridian, and the day of the month answering thereto, on the horizon, will be the day required.

Examples. 1. On what day of the month does Procyon come to the meridian of London at three o'clock in the morning?

*Answer.* Here the time is nine hours before noon; the globe must therefore be turned nine hours towards the west, the point of the ecliptic intersected by the brass meridian will then be the ninth of ♐, answering nearly to the first of December.

2. On what day of the month, and in what month does α, Alderamin, in Cepheus, come to the meridian of Edinburgh at ten o'clock at night?

*Answer.* Here the time is ten hours after noon; the globe must therefore be turned ten hours towards the east, the point of the ecliptic intersected by the brass meridian will then be the 17th of ♍, answering to the ninth of September.

3. On what day of the month, and in what month, does β, Deneb, in the Lion's tail, come to the meridian of Dublin at nine o'clock at night?

4. On what day of the month, and in what month, does Arcturus in Boötes come to the meridian of London at noon?

5. On what day of the month, and in what month, does δ in the Great Bear come to the meridian of London at midnight?

6. On what day of the month, and in what month, does Aldebaran come to the meridian of Philadelphia at five o'clock in the morning at London?

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* If the given star come to the meridian at noon, the sun's place will be found under the brass meridian, without turning the globe; if the given star come to the meridian at midnight, the globe may be turned either eastward or westward till the [redacted]

## PROBLEM XCIV.

*The day of the month being given, to find at what hour any given star comes to the meridian.*[*]

RULE. Find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12; turn the globe westward on its axis till the given star comes to the brass meridian, and the hours passed over by the index will be the time from noon when the star culminates.

### OR, WITHOUT THE GLOBE.

Subtract the right ascension of the sun for the given day from the right ascension of the star, and the remainder will be the time of the star's culminating *nearly*.[†]—If the sun's right ascension exceed the star's, add twenty-four hours to the star's before you subtract.

EXAMPLES. 1. At what·hour does Cor Leonis, or Regulus, come to the meridian of London on the 23d of September?

*Answer.* The index will pass over 21¾ hours; hence this star culminates or comes to the meridian 21¾ hours after noon, or at three quarters past nine o'clock in the morning.

2. At what hour does Arcturus come to the meridian of London on the 9th of February?

*Answer.* The index will pass over 16½ hours; hence Arcturus culminates 16½ hours after noon, or at half-past four o'clock in the morning.

3. Required the hours at which the following stars come to the meridion of London on the respective days annexed.

Bellatrix, January 9th.
Menkar, May 18th.
ε Draco, Sept. 22d.
α Dubhe, Dec. 20th.
β Mirach, October 5th.
Aldebaran, Feb. 12th.
β Aries, November 5th.
ε Taurus, January 24th.

4. At what time did Sirius come to the meridian of Greenwich on the 18th of December, 1825, his right ascension being 99° 22′ 49″, and the sun's right ascension 266° 1′ 57″.

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[*] This Problem is comprehended in Problem LXXI.

[†] Vide *Keith's* Trigonometry, *fourth* edition, p. 273.

## PROBLEM XCV.

*Given the azimuth of a known star, the latitude, and the hour, to find the star's altitude and the day of the month.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the given place, screw the quadrant of altitude upon the brass meridian over that latitude, bring the division marked o on the lower end of the quadrant to the given azimuth on the horizon, turn the globe till the star coincides with the graduated edge of the quadrant, and set the index of the hour-circle to 12; then, if the given time be before noon, turn the globe westward till the index has passed over as many hours as the time wants of noon; if the given time be past noon, turn the globe eastward till the index has passed over as many hours as the time is past noon; observe that degree of the ecliptic which is intersected by the graduated edge of the brass meridian, and the day of the month answering thereto, on the horizon, will be the day required.

Examples. 1. At London, at ten o'clock at night, the azimuth of Spica Virginis was observed to be 40 deg. from the south towards the west; required its altitude, and the day of the month.

*Answer.* The star's altitude is 20 deg. and the day is the 18th of June. The time being 10 hours past noon, the globe must be turned ten hours towards the east.

2. At London, at four o'clock in the morning, the azimuth of Arcturus was 70 deg. from the south towards the west; required its altitude and the day of the month.

*Answer.* Here the time wants eight hours of noon, therefore the globe must be turned eight hours westward: the altitude of the star will be found to be 40 deg., and the day the 12th of April.

3. At Edinburgh, at eleven o'clock at night, the azimuth of α Serpentarius, or Ras Alhagus, was 60 deg. from the south towards the east; required its altitude, and the day of the month.

4. At Dublin, at two o'clock in the morning, the azimuth of β Pegasus, or Scheat, was 70 deg. from the north towards the east; required its altitude and the day of the month.

## PROBLEM XCVI.

*The altitude of two stars being given, to find the latitude of the place.*

**Rule.** Subtract each star's altitude from 90 deg.; take successively the extent of the number of degrees, contained in each of the remainders, from the equinoctial, with a pair of compasses; with the compasses thus extended, place one foot successively in the centre of each star, and describe arcs on the globe with a blacklead pencil; these arcs will cross each other in the zenith; bring the point of intersection to that part of the brass meridian which is numbered from the equinoctial towards the poles, and the degree above it will be the latitude.*

**Examples.** 1. At sea, in north latitude, I observed the altitude of Capella to be 30 deg., and that of Aldebaran 35 deg.; what latitude was I in?

*Answer.* With an extent of 60 deg. (=90°—30°) taken from the equinoctial, and one foot of the compasses in the centre of Capella, describe an arc towards the north; then with 55 deg. (=90°—55°), taken in a similar manner, and one foot of the compasses in the centre of Aldebaran, describe an other arc, crossing the former; the point of intersection brought to the brass meridian will show the latitude to be 20½ deg. north.

2. The altitude of Markab in Pegasus was 30 deg., and that of Altair in the Eagle, at the same time, was 65 deg.; what was the latitude, supposing it to be north?

3. In north latitude the altitude of Arcturus was observed to be 60 deg., and that of β or Deneb, in the Lion's Tail, at the same time, was 70 deg.; what was the latitude?

4. In north latitude, the altitude of Procyon was observed to be 50 deg., and that of Betelgeux in Orion, at the same time, was 58 deg.; required the latitude of the place of observation.

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* The arc described in the rule will intersect twice; and therefore if both points of intersection be within 90 degrees of the elevated pole, there will be two answers to the problem, or the required latitude will be ambiguous: if only one intersection be within 90 degrees of the elevated pole there will be no ambiguity, as the zenith must be within 90 degrees of the elevated pole. If it were unknown on which side of the equator the observations were made, either pole may be elevated, and the zenith or zeniths will be found as before.

## PROBLEM XCVII.

*The meridian altitude of a known star being given, at any place in north latitude, to find the latitude.*

**Rule.** Bring the given star to that part of the brass meridian which is numbered from the equinoctial towards the poles; count the number of degrees in the given altitude on the brass meridian from the star towards the south part of the horizon, and mark where the reckoning ends; elevate or depress the pole till this mark coincides with the south point of the horizon, and the elevation of the north pole above the north point of the horizon will show the latitude.

**Examples.** 1. In what degree of north latitude is the meridian altitude of Aldebaran 52½ deg.?

*Answer.* 53 deg. 36 min. north.

2. In what degree of north latitude is the meridian altitude of $\beta$, one of the pointers in Ursa Major, 90 deg.?

3. In what degree of north latitude is $\gamma$, in the head of Draco, vertical when it culminates?

4. In what degree of north latitude is the meridian altitude of $\iota$ or Mirach in Boötes, 68 degrees?

## PROBLEM XCVIII.

*The latitude of a place, day of the month, and hour of the day, being given, to find the* NONAGESIMAL DEGREE* *of the ecliptic, its altitude and azimuth, and the* MEDIUM CŒLI.

**Rule.** Elevate the north pole to the latitude of the given place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12;

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* The nonagesimal degree of the ecliptic is that point which is the most elevated above the horizon, and is measured by the angle which the ecliptic makes with the horizon at any elevation of the pole; or, it is the distance between the zenith of the place and the pole of the ecliptic. This angle is frequently used in the calculation of solar eclipses. The medium cœli, or mid-heaven, is that point of the ecliptic which is upon the meridian.

then if the given time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; but, if the given time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon, and fix the globe in this position; count 90 deg. upon the ecliptic from the horizon (either eastward or westward), and mark where the reckoning ends, for that point of the ecliptic will be the nonagesimal degree, and the degree of the ecliptic cut by the brass meridian will be the medium cœli; bring the graduated edge of the quadrant of altitude to coincide with the nonagesimal degree of the ecliptic thus found, and the number of degrees on the quadrant, counted from the horizon, will be the altitude of the nonagesimal degree: the azimuth will be seen on the horizon.

**Examples.** 1. On the 21st of June, at forty-five minutes past three o'clock in the afternoon at London, required the point of the ecliptic which is the nonagesimal degree, its altitude and azimuth, the longitude of the medium cœli, and its altitude, &c.

*Answer.* The nonagesimal degree is 10 deg. in Leo. its altitude is 54 deg., and its azimuth 22 deg. from the south towards the west, or nearly S. S. W. The mid-heaven, or point of the ecliptic under the brass meridian, is 24 deg. in Leo, and its altitude above the horizon is 52 deg. The degree of the equinoctial cut by the brass meridian, reckoning from the point Aries, is the right ascension of the mid-heaven, which in this example is 146 degrees. The rising point of the ecliptic will be found to be 10 deg. in Scorpio, and the setting point 10 degrees in Taurus. If the graduated edge of the quadrant be brought to coincide with the sun's place, the sun's altitude will be found to be 39 deg., and his azimuth 78½ deg. from the south towards the west, or nearly W. by S.

2. At London, on the 24th of April, at nine o'clock in the morning; required the point of the ecliptic which is the nonagesimal degree, its altitude and azimuth, the point of the ecliptic which is the mid-heaven, &c. &c.

3. At Limerick, in 52 deg. 22 min. north latitude, on the 15th of October, at 5 o'clock in the afternoon; required the point of the ecliptic which is the nonagesimal degree, its altitude and azimuth, the point of the ecliptic which is the mid-heaven, &c. &c.

4. At Dublin, in latitude 53 deg. 21 min. north, on the 15th of January, at two o'clock in the afternoon; required the longitude, altitude and azimuth, of the nonagesimal degree; and the longitude and altitude of the medium cœli, &c. &c.

## PROBLEM XCIX.

*The latitude of a place, day of the month, and the hour, together with the altitude and azimuth of a star, being given, to find the star.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian over that latitude: find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12; then, if the given time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; but, if the time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon; let the globe rest in this position, and bring the division marked ○ on the quadrant to the given azimuth on the horizon; then, immediately under the given altitude on the graduated edge of the quadrant, you will find the star.

Examples. 1. At London, on the 21st of December, at four o'clock in the morning, the altitude of a star was 50°, and its azimuth was 37° from the south towards the east, required the name of the star.

*Answer.* Deneb, or β in the Lion's tail.

2. The altitude of a star was 27°, its azimuth 76⅓° from the south towards the west, at 11 o'clock in the evening at London, on the 11th of May; what star was it?

3. At London, on the 21st of December, at four o'clock in the morning, the altitude of a star was eight degrees, and its azimuth 51° from the south towards the west; required the name of the star.

4. At London, on the first of September, at nine o'clock in the evening, the altitude of a star was 47°, and its azimuth 73° from the south towards the east; required the name of the star.

## PROBLEM C.

*To find the time of the moon's southing, or coming to the meridian of any place, on any given day of the month.*

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the given place; find the moon's latitude and longitude, or her right ascension and declination, from an ephemeris, and mark her place on the globe; bring the sun's place to the brass meridian, and set the index of the hour-circle to 12; turn the globe westward till the moon's place comes to the meridian, and the hours passed over by the index will show the time from noon when the moon will be upon the meridian.

### Or, without the globe.

Find the moon's age by the table, at page 176, which multiply by 81*, and cut off two figures from the right hand of the product, the left-hand figures will be the hours; the right-hand figures must be multiplied by 60, for minutes.

### Or, correctly, thus:

Take the difference between the sun's and moon's right ascension in 24 hours; then, as 24 hours diminished by this difference is to 24 hours, so is the moon's right ascension at noon, diminished by the sun's, to the time of the moon's transit.

Examples. 1. At what hour, on the 10th of April 1825, did the moon pass over the meridian of Greenwich? The moon's right ascension at midnight being 301° 15′, and her declination 17° 16′ south.

*Answer. By the Globe.*—The moon came to the meridian at three quarters past six in the morning.†

*By the Table, page* 176.—The moon's age was 23; this multiplied by 81 produces 1863, that is, 18 hours and 63 over; this 63, multiplied by 60, produces 3780, which, by rejecting the two right-hand figures, leaves 37 minutes; so that, by this method, the moon came to the meridian at 37 minutes past 6 o'clock in the morning.

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* For, the synodic revolution of the moon being about 29½ days, we have by the rule of three, as 29½ d. : 24 h. : : 1 d. : 81 h.

† The time of the moon's rising and setting may be found as for a star or a planet, see Problem LXXI.; but on account of the moon's swift and irregular motion, the solution will differ materially from the truth.

*By using the Nautical Almanac.*

Sun's right ascension at noon 10th April = 1 h. 15′ 1″ 6
Ditto - - - 11th April = 1 18 41 6

Increase of motion in 24 hours - 0 3 40

Moon's right ascension at noon 10th April = 294° 59′ 11″
Ditto - - - 11th April = 307° 20′ 12″

Increase in 24 hours - - - 12° 21′ 1″ equal to 49′ 24″; hence 49′ 24″ diminished by 3′ 40″, leaves 45′ 44″ the moon's motion exceeds the sun's in 24 hours.

Moon's right ascension 294° 59′ + 4 =* 19 h. 39′ 56″
Sun's right ascension - - - 1 15 1.6

18 24 54.4

24h.—45′ 44″ : 24h. : : 18h. 24′ : 54″ 4, the true time of the moon's passage over the meridian in the morning, agreeing exactly with the Nautical Almanac.

2. At what hour, on the first of January, 1826, will the moon pass over the meridian of Greenwich, the moon's right ascension at noon being 187 deg. 46 min., and declination 8 degrees 20 min. south?

3. At what hour, on the 12th of March 1826, will the moon pass over the meridian of Greenwich, the moon's right ascension at midnight being 36 deg. 11 min., and declination 16 deg. 43 min. north?

4. At what hour, on the 17th of October 1826, will the moon pass over the meridian of Greenwich, the moon's right ascension at noon being 38 deg. 15 min., and declination 16 deg. 15 min. north?

## PROBLEM CI.

*The day of the month, latitude of the place, and time of high water at the full and change of the moon being given, to find the time of high water on the given day.*

Rule. Find the time at which the moon comes to the meridian of the given place by the preceding problem, to which add the time of high water at the given place at the full and change of the moon (taken from the following Table), and the sum will show the time of high water in the afternoon. If the sum exceed twelve hours, subtract 12 hours and 24 minutes from it, and the remainder will show the time of high water in the morning; but if the sum exceed 24 hours, subtract 24 hours and 48 minutes from it, and the remainder will show the time of high water in the afternoon.

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* When the sun's right ascension is greater than the moon's, 24 hours must be added to the moon's right ascension before you subtract.

### OR, BY THE TABLE, PAGE 176.

Find the moon's age by the Table, at page 176., and take out the time from the right-hand column thereof, answering to the moon's age; to which add the time of high water at the full and change of the moon (taken from the following Table), and the sum will show the time of high water in the afternoon. If the sum exceed 12 hours, subtract 12 hours and 24 minutes from it, and the remainder will show the time of high water in the morning; but, if the sum exceed 24 hours, subtract 24 hours and 48 minutes from it, and the remainder will show the time of high water in the afternoon.

### OR THUS:

Find the time of the moon's coming to the meridian of Greenwich on the given day, at page VI. of the Nautical Almanac; take out the correction (from the following Table) to correspond to this time, and apply it as the Table directs; to the result add the time of high water at the full and change of the moon (taken from the following Table), and the sum will show the time of high water in the afternoon. If the sum exceed 12 or 24 hours, proceed as above.

EXAMPLES. 1. Required the time of high water at London Bridge on the 2d of April 1825, the moon's right ascension at that time being 179 deg. 24 min., and her declination 5 deg. 10 min. south?

| | | |
|---|---|---|
| *Answer.* *By the Globe.*—The moon came to the meridian at | 11 h. | 15′ |
| Time of high water at the full and change at London - | 3 | 0 |
| Sum - - - - - | 14 | 15 |
| Subtract from it - - | 12 | 24 |
| Time of high water in the morning - - - - - | 1 | 51 |

### A TABLE
### Of the Time of High Water at New and Full Moon at the principal places in the British Islands.

| | | | |
|---|---|---|---|
| Aberdeen | 0h 45′ | Fifeness | 2h 0′ |
| Ayr | 10 30 | Flamborough Head | 3 40 |
| Aldborough | 9 40 | N. and S. Foreland | 10 20 |
| St. Andrew's | 2 0 | Fortrose | 11 40 |
| Arran Island | 11 0 | Foulness | 6 45 |
| Bamborough | 3 30 | Fowey | 5 40 |
| Banff | 0 0 | Galway | 3 0 |
| Beachy Head | 10 0 | Fort George | 11 40 |
| St. Bee's Head | 10 45 | Gravesend | 1 30 |
| Belfast | 10 0 | Greenock | 11 30 |
| Bembridge Point | 10 15 | Hartland Point | 4 30 |
| Berwick | 2 30 | Hartlepool | 3 0 |
| North Berwick | 2 0 | Harwich | 11 10 |
| St. Bride's Bay | 6 0 | Holyhead | 9 45 |
| Bridlington Bay | 3 50 | Hull | 6 0 |
| Bridport | 6 45 | Kinsale | 5 15 |
| Brighton | 9 50 | Leith | 2 20 |
| Bristol | 6 40 | Limerick | 4 30 |
| Caithness Point | 9 0 | Liverpool | 11 15 |
| Cantire, Mull, | 10 30 | London | 3 0 |
| Cape Clear | 4 30 | Milford | 5 15 |
| Cork | 6 30 | Newcastle | 3 15 |
| Cowes | 10 30 | Orfordness | 9 45 |
| Cromartie | 11 40 | Plymouth | 6 0 |
| Cromer | 7 0 | Port Glasgow | 11 30 |
| Cullen | 0 0 | Portland | 7 30 |
| Dartmouth | 6 30 | Ramsgate | 10 30 |
| Dingle Bay | 3 30 | Rochester | 0 45 |
| Dover | 11 30 | Sandwich | 11 30 |
| Dublin | 9 15 | Scarborough | 3 45 |
| Dunbar | 2 30 | Sligo | 5 30 |
| Dunbarton | 11 15 | Southampton | 0 0 |
| Dundee | 2 10 | Stockton | 3 30 |
| Dungarvon | 4 30 | Swansea | 6 0 |
| Dungeness | 9 45 | Tynemouth | 3 0 |
| Eddystone | 5 30 | Torbay | 6 15 |
| Edinburgh | 2 20 | Weymouth | 7 20 |
| Exeter | 10 30 | Whitby | 3 20 |
| Exmouth Bar | 6 20 | Whitehaven | 11 15 |
| Falmouth | 5 30 | Yarmouth | 9 0 |
| Fern Island | 3 30 | | |

| Time of the moon's passing the merid. Hours. | Correction to be subtracted, or added. H. M. |
|---|---|
| | Sub. |
| 0 | 0 0 |
| 1 | 0 1 |
| 2 | 0 34 |
| 3 | 0 50 |
| 4 | 1 3 |
| 5 | 0 9 |
| 6 | 1 3 |
| 7 | 0 35 |
| | Add. |
| 8 | 0 2 |
| 9 | 0 23 |
| 10 | 0 24 |
| 11 | 0 14 |
| 12 | 0 0 |
| | Sub. |
| 13 | 0 17 |
| 14 | 0 34 |
| 15 | 0 50 |
| 16 | 1 3 |
| 17 | 1 9 |
| 18 | 1 3 |
| 19 | 0 35 |
| | Add. |
| 20 | 0 2 |
| 21 | 0 23 |
| 22 | 0 24 |
| 23 | 0 14 |
| 24 | 0 0 |

## PROBLEM CII.

### *e the apparent path of any planet, or of a comet, amongst the fixed stars.*

**Rule.** Draw a straight line o, o, to represent the ecliptic, and divide it into any convenient number of equal parts. Set off eight of those equal parts northward and southward of the ecliptic, at each end thereof, and draw lines as in the figure Plate V.; these will represent the zodiac. Find the planet's geocentric latitude and longitude in an ephemeris, or in the Nautical Almanac, and mark its place for every month, or for several days in each month, beginning at the right hand of the ecliptic line, and proceeding towards the left.*

Find the latitudes and longitudes† of the principal stars in the several constellations near which the planet passes, and set them off in a similar manner from the right hand towards the left; you will thus have a complete picture of any part of the heavens, with the positions of the several stars, &c. as they appear to a spectator on the earth.

**Example.** Delineate the path of the planet Jupiter for the year 1811; the latitudes and longitudes being as follow.‡

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* The young student will recollect that the stars appear in a contrary order in the heavens to what they do on the surface of a globe. In the heavens we see the concave part, on the globe the convex. This manner of delineating the stars will be found extremely useful, and will enable the student to know their names and places sooner than by the globe.

† The places of the stars may likewise be laid down by their right ascensions and declinations, by drawing a portion of the equinoctial instead of the ecliptic.

‡ As Jupiter performs his revolution round the sun in 11 years 315 days (see page 156) he will have nearly the same longitude in the years 1823 and 1825, consequently he will pass through the same constellations as are delineated in Plate V.

| | Longitudes. | Latitudes. |
|---|---|---|
| Jan. 1st | 1s 21° 45′ | 0° 57′ S. |
| Feb. 7th | 1 22 11 | 0 47 S. |
| —— 25th | 1 23 58 | 0 43 S. |
| March 1st | 1 24 29 | 0 42 S. |
| —— 25th | 1 28 16 | 0 37 S. |
| April 1st | 1 29 35 | 0 36 S. |
| —— 25th | 2 4 30 | 0 32 S. |
| May 1st | 2 5 49 | 0 31 S. |
| —— 13th | 2 8 31 | 0 30 S. |
| —— 25th | 2 11 17 | 0 29 S. |
| June 1st | 2 12 54 | 0 28 S. |
| —— 25th | 2 18 27 | 0 26 S. |
| July 7th | 2 21 49 | 0 25 S. |
| July 25th | 2s 25° 1′ | 0° 24′ S. |
| Aug. 7th | 2 27 36 | 0 23 S. |
| —— 19th | 2 29 48 | 0 22 S. |
| —— 25th | 3 0 48 | 0 22 S. |
| Sept. 7th | 3 2 45 | 0 21 S. |
| —— 25th | 3 4 50 | 0 21 S. |
| Oct. 7th | 3 5 44 | 0 20 S. |
| —— 25th | 3 6 15 | 0 19 S. |
| Nov. 1st | 3 6 10 | 0 18 S. |
| —— 19th | 3 5 12 | 0 17 S. |
| —— 25th | 3 4 40 | 0 16 S. |
| Dec. 13th | 3 2 34 | 0 14 S. |
| —— 25th | 3 0 57 | 0 12 S. |

Jupiter's path, when delineated, will be south of the ecliptic in the order A, B, C, D, E, F, G, H. Thus, he will appear at A on the first of January, at B on the first of March, at C on the first of April, at D on the first of May, at E on the first of June, at F on the 7th of July, at G on the 25 of August, and at H on the 25th of October. On the 25th of August, when Jupiter appears at G, he will be a little to the right hand of the star marked η in Gemini; when he arrives at H, which will happen on the 25th of October, he will *apparently* return again to G, a small matter above his former path, where he will be situated on the 25th of December. Jupiter will not be visible during the *whole* of his apparent progress from A to H, being too near to the sun during the months of *May* and *June*.

In the same manner the places and situations of the stars may be delineated; thus Aldebaran, the principal star in the Hyades, will be found by the globe, (or a proper table) to be situated in 7° of ♊ and in 5¾° of south latitude; Betelgeux in ORION's right shoulder, is about 26° of ♊ and 16° of south latitude, and its place may be laid down on a map by extending the line of its longitude, as from L, till it meets a straight line passing through 16, 16, on the sides of the map. In the same manner any other star's situation may be described; thus the Hyades will appear at Q, the Pleiades at P, &c. and Bellatrix, &c. as in the figure.

The constellation ORION, here described, is a very conspicuous object in the heavens in the months of January and February, about 9 or 10 o'clock in the evening, and will be an excellent guide for determining the positions of several other constellations, particularly Canis Major, Canis Minor, Auriga, &c. See page 129.

# PART IV.

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CONTAINING

**1.** *A promiscuous Collection of Examples exercising the Problems on the Globes.—2. A collection of Questions, with References to the pages where the Answers will be found; designed as an Assistant to the Tutor in the Examination of the Scholar.*

## CHAPTER I.

### *A promiscuous Collection of Examples exercising the Problems on the Globes.*

1. WHAT day of the year is of the same length as the 14th of August?

2. How many miles make a degree of longitude in the latitude of Lisbon?

3. At what hour is the sun due east at London on the 5th of May?

4. There is a place in the parallel of 31 degrees of north latitude, which is 31 degrees distant from London; what place is it?

5. If the sun's meridian altitude at London be 30 degrees, what day of the month, and what month is it?

6. On what month and day is the sun's meridian altitude at Paris equal to the latitude of Paris?

7. When $\gamma$ Draconis is vertical to the inhabitants of London at ten o'clock at night; what day of the month, and what month is it?

8. What is the equation of time dependent on the obliquity of the ecliptic on the 14th of July?

9. I observed the pointers in the Great Bear, on the meridian of London, at eleven o'clock at night; in what month, and on what night, did this happen?

10. On what day of the month, and in what month, will the shadow of a cane placed perpendicular to the horizon of Lon-

don, at ten o'clock in the morning, be exactly equal in length to the cane?

11. The earth goes round the sun in 365 days 6 hours nearly; how many degrees does it move in one day, at a medium? Or, what is the daily apparent mean motion of the sun?

12. The moon goes once round her orbit, from the first point of the sign Aries to the same again, in 27 days 7 hours 43 min. 5 seconds: what is her mean motion in one day?

13. The moon turns round her axis, from the sun to the sun again, in 29 days 12 hours 44 minutes 3 seconds, which is exactly the time that she takes to go round her orbit from new moon to new moon; at what rate *per* hour are the inhabitants (if any) of her equatorial parts carried by this rotation, the moon's diameter being 2144 miles?

14. How many degrees does the motion of the moon exceed the apparent motion of the sun in 24 hours?

15. Find on what day, in any given month, the moon is eight days old, and then find her longitude for that day.

16. Travelling in an unknown latitude I found, by chance, an old horizontal dial; the hour-lines of which were so defaced by time that I could only discover those of IV. and V., and found their distance to be exactly 21 degrees; pray, what latitude was the dial made for?

17. Required the duration of twilight at the south pole.

18. How far must an inhabitant of London travel southward to lose sight of Aldebaran?

19. What is the elevation of the north polar star above the horizon of Calcutta?

20. Lord Nelson beat the French fleet near latitude 21 deg. 11 min. north, longitude 30 deg. 22 min. east; point out the place on the globe.

21. What is the sun's altitude at three o'clock in the afternoon at Philadelphia on the 7th of May?

22. What is the length of the day at London on the 26th of July, and how many degrees must the sun's declination be diminished to make the day an hour shorter?

23. At what hour does the sun first make his appearance at Petersburgh on the 4th of June?

24. At what rate *per* hour are the inhabitants of Botany Bay carried from west to east by the rotation of the earth on its axis?

25. When Arcturus is 30 degrees above the horizon of London, and eastward of the meridian, on the 5th of November, what o'clock is it?

scribe an horizontal dial for the latitude of Washington.

scribe a vertical dial facing the south for the latitude of
.

at is the moon's greatest altitude to the inhabitants of
n ?

What is the sun's greatest altitude at the southern extrem-
Patagonia ?

0. At what hour at London, on the 15th of August, will the
iades be on the meridian of Philadelphia ?

1. If a comet, whose longitude was 4 signs 5 deg., and latitude 44 deg. north, appeared in Ursa Major, in what part of the constellation was it ?

32. On what point of the compass does the sun set at Madrid, when constant twilight begins at London ?

33. What is the difference between the duration of twilight at Petersburgh and Calcutta, on the first of February ?

34. How much longer is the 10th of December at Madras than at Archangel ?

35. How much longer is the 5th of May at Archangel than at Madras ?

36. When it is two o'clock in the afternoon at London, on the 15th of February, to what places is the sun rising and setting, and where is it noon ?

37. Whether does the sun shine over the north or south pole on the 17th of April, and how far ?

38. At what hour on the 18th of April will the sun's altitude and azimuth, from the east towards the south, be each 40 degrees at London ?

39. Which way must a ship steer from Rio Janeiro to the Cape of Good Hope ?

40. Are the clocks at Philadelphia faster or slower than those at London, and how much ?

41. Are the clocks at Calcutta faster or slower than the clocks at London, and how much ?

42. What is the difference of latitude between Copenhagen and Venice ?

43. There is a place in latitude 31° 11′ north, situated, by an angle of position, south-east by east ½ east from London ; what place is that, and how far is it from London in English miles ?

44. On the 1st of February 1825, the longitude of Venus was 11 signs 25° 41′, latitude 0° 26′ south ; did Venus rise before or after the sun, and how much ?

45. On the 7th of September 1825, the longitude of Venus

4 min., latitude 0 deg. 51 min. south ; will
ter the sun, and how much ?
of December, 1826, the longitude of the
signs, 12 deg. 34 min., latitude 1 deg. 18
ur will he rise, come to the meridian, and

anuary 1825, the moon's longitude at mid-
g. 30 min., latitude 4 deg. 28 min. south ;
plitude at London, and the hour and azi-
deg. above the horizon.
gitude on the 5th of November 1826, at
gns, 4 deg. 1 min., latitude 4 deg. 59 min.
me of her rising, coming to the meridian,
, and the time of high water at London

of the earth will the moon be vertical on
1826, her longitude at midnight being 10
, and latitude 4 deg. 40 min. north ?
March, 1826, the moon's ascending node
. 14 min. ; where will the descending node

declination at midnight, on the 1st of Novem-
20 deg. 15 min. south ; to what places of the
vertical ?
are constantly above the horizon of Copenha-

d the altitude of Betelgeux to be 19 deg. and that
10 deg. ; they both appeared in the same azimuth,
st ; what latitude was I in ?
t latitude is Aldebaran on the meridian when $\beta$ in
il is rising ?
hat latitude is Rigel setting when Regulus is on the

what latitude are the pointers in the Great Bear on the
when Vega is rising ?
n latitude 79 deg. north, on the 1st of February, at what
ill Procyon and Regulus have the same altitude ?
At what hour on the 10th of February, will Capella and
yon have the same azimuth at London ?
9. On the 10th of November at eight o'clock in the evening,
llatrix in the left shoulder of Orion was rising : what was the
titude of the place ?

On the 16th of February, Arcturus rose at eight o'clock in vening; what was the latitude?

At what hour of the night, on the 16th of February, will altitude of Regulus be 28 deg. at London?

2. Required the altitude and azimuth of Markab in Pegasus, London, on the 21st of September, at nine o'clock in the eve-

On what day of the month, and in what month, will the inters of the Great Bear be on the meridian of London at midnight?

64. What inhabitants of the earth have the greatest portion of moon-light?

65. On what day of the year will Altair, in the Eagle, come to the meridian of London with the sun?

66. In what latitude north is the length of the longest day 11 times that of the shortest?

67. In what latitude south is the longest day eighteen hours?

68. At what time does the morning twilight begin, and at what time does the evening twilight end, at Philadelphia, on the 15th of January?

69. When it is four o'clock in the afternoon at London, on the 4th of June, where is it twilight?

70. Required the antipodes of Cape Horn.

71. Required the Periœci of Philadelphia.

72. Required the antœci of the Sandwich Islands.

73. What is the angle of position between London and Jerusalem?

74. Required the distance between London and Alexandria, in English and in geographical miles?

75. In what latitude north does the sun begin to shine constantly on the 10th of April?

76. How long does the sun shine without setting at the north pole; and what is the duration of dark night?

77. Where is the sun vertical when it is midnight at Dublin on the 15th of July?

78. When it is five o'clock in the evening at Philadelphia, where is it midnight, and where is it noon?

79. What places have the same hours of the day as Edinburgh?

80. What places have opposite hours to the respective capitals of Europe?

81. At what hour at London is the sun due east at the time of the equinoxes?

82. At what hour at London is the sun due east at the time of the solstices?

83. In what climates are the following places situated, viz. Philadelphia, Madrid, Drontheim, Trincomalé, Calcutta, and Astracan?

84. On what day of the year does Regulus rise heliacally at London?

85. On what day of the year does Betelgeux set heliacally at London?

86. What stars set acronically at London on the 24th of December?

87. What stars rise acronically at London on the 12th of December?

88. In what latitude north do the bright stars in the head of the Dolphin, and Altair in the Eagle, rise at the same hour?

89. In what latitude north do Capella and Castor set at the same hour, and what is the difference of time between their coming to the meridian?

90. What stars rise cosmically at London on the 7th of December?

91. What stars set cosmically at London the 10th of December?

92. What degrees of the ecliptic and equinoctial rise with Aldebaran at London?

93. On what day of the year does Arcturus come to the meridian of London, at two o'clock in the morning?

94. On what day of the year does Regulus come to the meridian of London, at nine o'clock in the evening?

95. At what time does Vega in Lyra come to the meridian of London, on the 18th of August?

96. Trace out the galaxy or milky-way on the celestial globe.

97. If the meridian altitude of the sun on the 7th of June be 50 deg., and south of the observer, what is the latitude of the place?

98. Required the sun's right and oblique ascension at London at the equinoxes.

99. Required the sun's right ascension, oblique ascension, ascensional difference, and time of rising and setting at London, on the 5th of May?

100. If the sun's rising amplitude on the 7th of June be 24 deg. to the northward of the east, what is the latitude of the place?

101. What stars have the following degrees of right ascensions and declinations?

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7° 10′ | R.A. | 29° 45′ | D.N. | | 162° 49′ | R.A. | 62° 50′ | D.N. |
| 14 38 | R.A. | 34 33 | D.N. | | 244 17 | R.A. | 25 28 | D.S. |
| 135 59 | R.A. | 3 10 | D.N. | | 238 27 | R.A. | 19 15 | D.S. |

102. Describe an horizontal sun-dial, for the latitude of Edinburgh.

103. What is the length of the day on February 14th at London, and how much must the sun's declination decrease to make the day an hour longer?

104. What hour is it at London when it is 17 minutes past 4 in the evening at Jerusalem?

105. On the 21st of June, the sun's altitude was observed to be 46 deg. 25 min., and his azimuth 112 deg. 59 min. from the north towards the east, at London; what was the hour of the day?

106. Given the sun's declination 17 deg. 2 min. north, and increasing; to find the sun's longitude, right ascension, and the angle formed between the ecliptic and the meridian passing through the sun.

107. Given the sun's right ascension 225 deg. 18 min. to find his longitude, declination, and the angle formed between the ecliptic and the meridian passing through the sun.

108. Given the sun's longitude 26 deg. 9 min. in ♉; to find his declination, right ascension, and the angle formed between the ecliptic and the meridian passing through the sun.

109. Given the sun's amplitude 39 deg. 50. min. from the east towards the north, and his declination 23½ deg. north; to find the latitude of the place, the time of the sun's rising and setting, and the length of the day and night.

110. At what time, on the first of April, will Arcturus appear upon the 6 o'clock hour-line at London, and what will his altitude and azimuth be at that time?

111. Required the altitude of the sun, and the hour he will appear due east at London, on the 20th of May.

112. At what hours will Arcturus appear due east and west at London, on the 2d of April, and what will its altitude be?

113. At London, the sun's altitude was observed to be 25 deg. 30 min. when on the prime vertical; required his declination and the hour of the day.

114. On the 25th of April 1826, the moon's right ascension at midnight will be 266 deg. 23 min., and her declination 21 deg. 18 min. south; required her distance from Regulus, Procyon, and Betelguex, at that time?

115. The distance of a comet from Sirius was observed to be

66 deg., and from Procyon 51 deg. 6 min.; the comet was westward of Sirius: required its latitude and longitude.

116. Find the Golden Number, the Epact, Sunday Letter, the Number of Direction, the Paschal full moon, and Easter day, for the years 1826, 1828, 1835, and 1840, distinguishing the leap-years.

117. The declination of $\gamma$ in the head of Draco is 51 deg. 31 min. north; to what places will it be vertical when it comes to their respective meridians?

118. When it is four o'clock in the evening at London on the 4th of May, to what places is the sun rising and setting, where is it noon and midnight, and to what place is the sun verical?

119. At what time does the sun rise and set at the North Cape, on the North of Lapland, on the 5th of April, and what is the length of the day and night?

120. At what time does the sun rise at the Shetland Islands when it sets at four o'clock in the afternoon at Cape Horn?

121. Walking in Kensington Gardens on the 17th of May, it was twelve o'clock by the sun-dial, and wanted eight minutes to twelve by my watch; was my watch right?

122. If the sun set at nine o'clock, at what time does it rise, and what is the length of the day and night?

123. Where is the sun vertical when it is five o'clock in the morning at London on the 15th of May?

124. At what hour does day break at London on the 5th of April?

125. If the moon be five days old on the 9th of June 1826, at what time does she rise, culminate, and set, at London?

126. On what day of the month, and in what month, does the sun rise 24 deg. to the north of the east at London?

127. When the sun is rising to the inhabitants of London on the 8th of May, where is it setting?

128. When the sun is setting to the inhabitants of Calcutta, on the 18th of March, where is it midnight?

129. What is the difference between the circumference of the earth at the equator and at Petersburgh, in English miles?

130. At what hour does the sun rise at Barbadoes when constant twilight begins at Dublin?

131. When the sun is rising at Owhyhee on the 18th of May, where is it noon?

132. At what hour does the sun rise at London when it sets at seven o'clock at Petersburg?

133. How high is the north polar star above the horizon of Quebec?

134. How many English miles must an inhabitant of London travel southward, that the meridian altitude of the north polar star may be diminished 25 degrees?

135. How many English miles must I sail or travel westward from London that my watch may be seven hours too fast?

136. What place of the earth has the sun in the zenith, when it is seven o'clock in the morning at London, on the 25th of April?

137. On what day of the month, and in what month, is the sun's amplitude at London equal to one-third of the latitude?

138. On what month and day is the sun's amplitude at London equal to the latitude of Kingston, in Jamaica?

139. If the moon be three days old on the 10th of March 1826, what is her longitude?

140. If the highest point of Mont Blanc be 5101 yards above the level of the sea, what would be its altitude on a globe of 18 inches in diameter?

141. If the polar diameter of the earth be to the equatorial diameter as 229 is to 230, what would the polar diameter of a three-inch globe be, if constructed on this principle?

142. What inhabitants of the earth, in the course of 12 hours, will be in the same situation as their antipodes?

143. On what day of the year at London is the twilight eight hours long?

144. At what time does the sun rise and set at London when the inhabitants of the north pole begin to have dark night?

145. At what hour does the sun set at the Cape of Good Hope, when total darkness ends at the north pole?

146. What is the moon's longitude if full moon happens on the 2d of April 1825?

147. Does the sun ever rise and set at the north pole?

148. At what hour of the day, on the 15th of April, will a person at London have his shadow the shortest possible?

149. If the precession of the equinoxes be $50\frac{1}{4}$ seconds in a year, how many years will elapse before the constellation Aries will coincide with the solstitial colure?

150. If the obliquity of the ecliptic be continually diminishing at the rate of 56 seconds in a century, as stated by several authors, how many years will elapse from the 1st of January 1825, when the obliquity of the ecliptic was 23 degrees 27 minutes 44 seconds, before the ecliptic will coincide with the equinoctial?

151. Required the duration of dark night at the south of Nova Zembla.

152. When constant twilight ends at Petersburgh, where is the day 18 hours long?

153. At what hour does the sun set at Constantinople, when it rises 12 degrees to the north of the east?

154. What is the difference between a solar and a siderial year, and what does that difference arise from?

155. What is the difference between the length of a natural or astronomical day and a siderial day, and how does the difference arise?

156. Required the difference between the length of the longest day at Cape Horn and at Edinburgh.

157. If one man were to travel eight miles a day westward round the earth at the equator, and another two miles a day westward round it in the latitude of 80 degrees north; in how many days would each of them return to the place whence he set out?

158. If a pole of 18 feet in length be placed perpendicular to the horizon of London on the 15th of July, and another exactly of the same length be placed in a similar manner at Edinburgh, which will cast the longer shadow at noon?

159. If the moon be in 29 degrees of Leo at the time of new moon, what sign and degree will she be in when she is five days old?

160. What is the duration of constant day or twilight at the north of Spitzbergen?

161. What place upon the globe has the greatest longitude, the least longitude, no longitude, and every longitude?

162. In what latitude is the length of the longest day, to the length of the shortest, in the ratio of 3 to 2?

163. If a man of six feet high were to travel round the earth, how much farther would his head go than his feet?

164. On what day of the week will the tenth of January fall in the year 1835?

165. At what hour, in the afternoon, London time, on the 21st of June, will the shadow of a pole ten feet high at Barbadoes, be of the same length as the meridional shadow of a similar pole at London on the same day?

166. One end of a wall declines 30 degrees from the east towards the north, and the other end 60 deg. from the south towards the west in latitude 51° 30′ N.; at what hour on the 21st

of June does the sun begin to shine on the south of the wall, and at what hour does it leave it?

167. The south wall of a church declines 12 deg. 30 min. towards the east, in latitude 52 deg. N., against which a vertical dial is fixed; for how many hours will the sun shine upon that dial on the tenth of May?

168. A clock, with a pendulum that beat seconds, and kept true time on the surface of the earth, was carried to the top of a mountain, and there lost 3 seconds in an hour; what was the height of the mountain?

# CHAPTER II.

*A Collection of Questions, with References to the Pages where the Answers will be found; designed as an Assistant to the Tutor* in the examination of the Student.*

1. How many kinds of artificial globes are there?

2. What does the surface of the terrestrial globe represent, and which way is its diurnal motion? page 1.

3. What does the surface of the celestial globe exhibit, which way is its diurnal motion, and where is the student supposed to be situated when using it?

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* Though a reference be given to the pages where the answers to each question may be found; yet, perhaps, it would be better for the student not to learn the answers by heart, verbatim from the book; but to frame an answer himself, from an attentive perusal of his lesson: by which means the understanding will be called into exercise as well as the memory.

### I. GREAT CIRCLES ON THE TERRESTRIAL GLOBE.

1. What is a GREAT CIRCLE, and how many are there drawn on the terrestrial globe? *Definition* 6, page 26.

2. What is the equator, and what is its use? *Def.* 10, page 26.

3. What are the meridians, and how many are drawn on the terrestrial globe? *Def.* 8, page 26.

4. What is the first meridian? *Def.* 9, page 26.

5. What is the ecliptic, and where is it situated? *Def.* 11, page 27.

6. What are the colures, and in how many parts do they divide the ecliptic? *Def.* 14, page 28.

7. What are the hour-circles, and how are they drawn on the globe? *Def.* 50, page 34.

8. What hour-circle is called the six o'clock hour line? *Def.* 51, page 35.

9. What are the azimuth or vertical circles, and what is their use? *Def.* 43, page 33.

10. What is the prime vertical? *Def.* 44, page 34.

### II. SMALL CIRCLES ON THE TERRESTRIAL GLOBE.

1. What is a SMALL CIRCLE, and how many are generally drawn on the terrestrial globe? *Def.* 7, page 26.

2. What are the tropics, and how far do they extend from the equator, &c.? *Def.* 16, page 29.

3. What are the polar circles, and where are they situated? *Def.* 17, page 29.

4. What are the parallels of latitude, and how many are generally drawn on the terrestrial globe? *Def.* 18, page 29.

5. What circles are called Almacanters? *Def.* 40, page 33.

### III. GREAT CIRCLES ON THE CELESTIAL GLOBE.

1. How many GREAT CIRCLES are drawn on the celestial globe?

2. The lines of terrestrial longitude are perpendicular to the equator, on the terrestrial globe, and all meet in the poles of the

world; to what great circle on the globe are the lines of celestial longitude perpendicular, and on what points of the globe do they all meet.

3. What are the colures, and into how many parts do they divide the ecliptic? *Def.* 14, page 28.

4. What is the equinoctial, and what is its use? *Def.* 10, page 27.

5. What is the ecliptic, and where is it situated? *Def.* 11, page 27.

6. What is the zodiac, and into how many parts is it divided? *Def.* 12, page 27.

7. What are the signs of the zodiac, and how are they marked? *Def.* 13, page 28.

8. What are the spring, summer, autumnal, and winter signs; and on what days does the sun enter them? *Def.* 13, page 28.

9. What are the ascending and descending signs? *Def.* 13, page 28.

## IV. SMALL CIRCLES ON THE CELESTIAL GLOBE.

1. How many SMALL CIRCLES are drawn on the celestial globe?

2. What are the tropics, and how far do they extend from the equinoctial? *Def.* 16, page 6.

3. What are the polar circles, and where are they situated? *Def.* 17, page 29.

4. What are the parallels of celestial latitude? *Def.* 41, page 33.

5. What are the parallels of declination? *Def.* 42, page 33.

## V. THE BRASS MERIDIAN, AND OTHER APPENDAGES TO THE GLOBES.

1. What is the brazen meridian, and how is it divided and numbered? *Def.* 5, page 26.

2. What is the axis of the earth, and how is it represented by the artificial globes? *Def.* 3, page 25.

3. What are the poles of the world? *Def.* 4, page 26.

4. What are the hour-circles, and how are they divided? *Def.* 19, page 29.

5. What is the horizon, and what is the distinction between

the rational and sensible horizon? *Defs.* 20, 21, and 22, pages 29 and 30.

6. What is the wooden horizon, and how is it divided? *Def.* 23, page 30.

7. What is the mariner's compass, how is it divided, and what is the use made of it on the globe? *Defs.* 33, 34, and note page 32.

8. What is the quadrant of altitude, how is it divided, and what is its use? *Def.* 37, page 33.

### VI. POINTS ON, AND BELONGING TO, THE GLOBES.

1. What is the pole of a circle? *Def.* 29, page 31.

2. What is the zenith, and of what circle is it the pole? *Def.* 27, page 31.

3. What is the nadir, and of what circle is it the pole? *Def.* 28, page 31.

4. Where are the cardinal points of the horizon? *Def.* 24, page 31.

5. What are the cardinal points in the heavens? *Def.* 25, page 31.

6. What are the cardinal points of the ecliptic, and which are the cardinal signs? *Def.* 26, page 31.

7. What are the equinoctial points? *Def.* 30, page 31.

8. What are the solstitial points? *Def.* 31, page 31.

9. What is the culminating point of a star, or of a planet? *Def.* 52, page 35.

10. What are the poles of the ecliptic, how far are they from the poles of the world, and in what circles are they situated? *Def.* 29, page 31.

### VII. LATITUDE AND LONGITUDE ON THE TERRESTRIAL GLOBE, THE DIVISION OF THE GLOBE INTO ZONES AND CLIMATES, THE POSITIONS OF THE SPHERE, THE SHADOWS, AND POSITIONS OF THE INHABITANTS WITH RESPECT TO EACH OTHER.

1. What is the latitude of a place on the terrestrial globe? *Def.* 35, page 32.

2. What is the longitude of a place on the terrestrial globe? *Def.* 38, page 33.

3. What is a zone, and how many are there on the terrestrial globe? *Def.* 70, page 40.

4. What is the situation, and what is the extent of the torrid zone? *Def.* 71, page 40.

5. Where are the two temperate zones situated, and what is the extent of each? *Def.* 72, page 40.

6. Where are the two frigid zones situated, and what is the extent of each? *Def.* 73, page 41.

7. What is a climate, and how many are there on the globe? *Def.* 69, page 38.

8. Have all places in the same climate the same atmospherical temperature? *Note*, page 38.

9. How many different positions of the sphere are there? *Def.* 65, page 38.

10. What is a right sphere, and what inhabitants of the globe have this position? *Def.* 66, page 38; see likewise Prob. XXII. page 205.

11. What is a parallel sphere, and what inhabitants of the globe have this position? *Def.* 67, page 38; and *Prob.* XXII. page 206, &c.

12. What is an oblique sphere, and what inhabitants of the globe have this position? *Def.* 68, page 38; and *Prob.* XXII. page 207, &c.

13. What parts of the globe do the AMPHISCII inhabit, and why are they so called? *Def.* 74, page 41.

14. When do the AMPHISCII obtain the name of ASCII?

15. What parts of the globe do the HETEROSCII inhabit, and why are they so called? *Def.* 75, page 41.

16. What parts of the globe do the PERISCII inhabit, and why are they so called? *Def.* 76, page 41.

17. What inhabitants are called ANTOECI to each other, and what do you observe with respect to their latitudes, longitudes, hours, &c.? *Def.* 77, page 41.

18. What inhabitants are called PERIOECI to each other, and what is observed with respect to their latitudes, longitudes, hours, seasons, &c.? *Def.* 78, page 41.

19. Where are the ANTIPODES, and what is observed with respect to their seasons of the year, &c.? *Def.* 79, page 41.

## VIII. LATITUDES AND LONGITUDES OF THE STARS AND PLANETS ON THE CELESTIAL GLOBE, &C. TOGETHER WITH THE POETICAL RISING AND SETTING OF THE STARS, &C.

1. What is the latitude of a star or planet? *Def.* 36, page 33.

2. What is the longitude of a star or planet? *Def.* 39, page 33.

3. What are the fixed stars, and why are they so called? *Def.* 89, page 45.

4 What is a constellation, and how many are there on the celestial globe? *Def.* 91, page 46; see the tables, pages 46, 47, and 48.

5. What is meant by the poetical rising and setting of the stars? *Def.* 90, page 45.

6. When is a star said to rise and set cosmically?

7. When is a star said to rise and set acronically?

8. When is a star said to rise and set heliacally?

9. What is the Via Lactea, and through what constellation does it pass? *Def.* 92, page 53.

10. What kind of stars are termed nebulous? *Def.* 93, page 54.

11. How are the stars, which have not particular names, distinguished on the celestial globe? *Def.* 94, page 54.

## IX. DEFINITIONS AND TERMS COMMON TO BOTH THE GLOBES.

1. What is the declination of the sun or star, or planet? *Def.* 15, page 28.

2. What is an hemisphere? *Def.* 32, page 32.

3. What is the altitude of any object in the heavens? *Def.* 45, page 34.

4. What is the meridian altitude of the sun, a star, or planet?

5. What is the zenith distance of a celestial object? *Def.* 46, page 34.

6. What is the polar distance of a celestial object? *Def.* 47, page 34.

7. What is the amplitude of a celestial object? *Def.* 48, page 34.

8. What is the azimuth of a celestial object? *Def.* 49, page 34.

9. What is the right ascension of the sun, or of a star, &c.? *Def.* 80, page 41.

10. What is the oblique ascension of the sun, or of a star, &c.? *Def.* 81, page 42.

11. What is the oblique descension of the sun, or of a star, &c.? *Def.* 82, page 42.

12. What is the ascensional or descensional difference? *Def.* 83, page 42.

## X. TIME; YEARS, DAYS, &c.

1. What is a solar or tropical year, and what is the length of it? *Def.* 62, page 37.

2. What is a siderial year, and what is its duration? *Def.* 63, page 37.

3. What is an astronomical day? *Def.* 58, page 36.

4. What is a mean solar day? *Def.* 57, page 35.

5. What is a true solar day? *Def.* 56, page 35.

6. What is an artificial day? *Def.* 59, page 36.

7. What is a civil day? *Def.* 60, page 36.

8. What is a siderial day? *Def.* 61, page 36.

9. What is meant by apparent noon, or apparent time? *Def.* 53, page 35.

10. What is true or mean noon? *Def.* 54, page 35.

11. What is the equation of time at noon? *Def.* 55, page 35.

12. What is the calendar? page 171.

13. What is the cycle of the moon, and how is it found? page 171.

14. What is the epact, what is its use, and how is it found? page 171.

15. What is the cycle of the sun, how is it found, and to what use is it applied? page 172.

16. What is the number of direction, and how is Easter found by it? page 173.

17. How do you find the Paschal full moon and Easter by the Epact? page 174.

18. In how many years will the error in the Gregorian calendar amount to *one* day? page 177.

19. In what manner do you find the moon's age, the time of new moon, and the time of full moon, by the table page 176.

## XI. ASTRONOMICAL AND MISCELLANEOUS DEFINITIONS, &C.

1. What do you understand by the precession of the equinoxes, and in what time do they make an entire revolution around the equinoctial? *Def.* 64, page 37.

2. What is the crepusculum or twilight, and what is the cause of it? *Def.* 84, page 42.

3. What is refraction, and whence does it arise? *Def.* 85, pages 42, 43 and 44.

4. What is meant by the parallax of the celestial bodies? *Def.* 86, page 44.

5. What is an angle of position between two places? *Def.* 87, page 44; and note, pages 199 and 200.

6. What are rhumbs and rhumb-lines? *Def.* 88, page 45.

7. What are the planets, and how many belong to the solar system? *Def.* 95, page 55.

8. What is the distinction between primary and secondary planets, and how many secondary planets belong to the solar system? *Defs.* 96, and 97, page 55.

9. What is the orbit of a planet? *Def.* 98, page 55. Of what figure are the orbits of the planets, and in what part of the figure is the sun placed? page 143.

10. What are the nodes of a planet? *Def.* 99, page 56.

11. What are the different aspects of the planets, and how many are there? *Def.* 100, page 56.

12. What are the syzygies and quadratures of the moon?

13. When is a planet's motion said to be direct, stationary, or retrograde? *Defs.* 101, 102, and 103, page 56.

14 What is a digit? *Def.* 104, page 56.

15. What is the disc of the sun or moon? *Def.* 105, page 56.

16. What are the geocentric and heliocentric latitudes and longitudes of the planets? *Defs.* 106 and 107, page 56.

17. When is a planet said to be in apogee? *Def.* 108, page 56.

18. When is a planet said to be in perigee? *Def.* 109, page 56.

19. What is the aphelion or higher apsis of a planet's orbit? *Def.* 110, page 56.

20. What is the perihelion or lower apsis of a planet's orbit? *Def.* 111, page 57.

21. What is the line of the apsides? *Def.* 112, page 57.

22. What is the eccentricity of the orbit of a planet? *Def.* 113, page 57.
23. What is the elongation of a planet? *Def.* 118, page 57.
24. What are the occultation and transit of a planet? *Defs.* 114 and 115, page 57.
25. What is the cause of an eclipse of the sun? *Def.* 116, page 57.
26. What is the cause of an eclipse of the moon? *Def.* 117, page 57.
27. What are the nocturnal and diurnal arcs described by the heavenly bodies? *Defs.* 119, and 120, page 57.
28. What is the aberration of a star? *Def.* 112, page 57.
29. What are the centripetal and centrifugal forces? *Defs.* 122 and 123, page 58.
30. What is gravity? *Def.* 8, page 63.
31. What is the vis inertiæ of a body? *Def.* 9, page 63.
32. What is matter, and what are its general properties? *Defs.* 1 and 2, page 62.
33. What are extension, figure, and solidity? *Defs.* 3, 4, and 5, page 62.
34. Can matter be divided *ad infinitum?* *Def.* 7, page 60.
35. What is motion, and what is the distinction between *absolute* and *relative* motion? *Def.* 6, page 62, and *Def.* 10, page 63.
36. How is the velocity of a body measured, and what do you understand by the word force? *Defs.* 11 and 12, page 64.
37. What are Sir I. Newton's three laws of motion? pages 64 and 65.
38. What is compound motion? page 65.

## XII. THE SOLAR SYSTEM AND THE SUN, ☉.

1. What is the solar system, and why is it so called? page 139.
2. What part of the solar system is called the centre of the world? page 140.
3. Does not the sun revolve on its axis, and what other motion has it? page 140.
4. Of what shape is the sun, how far is it from the earth, and how many miles is it in diameter? pages 140 and 141.

5. What is the comparative magnitudes of the sun and the earth? page 141.

## XIII. OF MERCURY, ☿.

1. What is the length of Mercury's year? page 142.
2. What is the greatest elongation of Mercury?
3. What is the distance of Mercury from the sun?
4. What is the diameter of Mercury? page 142.
5. What is the comparative magnitudes of Mercury and the earth?
6. What is the comparison between the light and heat which Mercury receives from the sun, and the light and heat which the earth receives? page 143.
7. At what rate per hour are the inhabitants of Mercury (if any) carried round the sun? page 143.

## XIV. OF VENUS ♀.

1. When is Venus an evening star, and in what situation is she a morning star? page 144.
2. How long is Venus a morning star?
3. In how many days does Venus revolve around the sun?
4. The last transit of Venus over the sun's disc happened in 1769, when will the next transit happen?
5. What is the opinion of Dr. Herschel respecting the mountains in Venus? page 145.
6. What is the opinion of M. Schroeter on the same subject? page 152 in the note.
7. What is the greatest elongation of Venus? page 145.
8. What is the diameter of Venus?
9. What is the magnitude of Venus?
10. What is the distance of Venus from the sun?
11. What is the comparison between the light and heat which Venus receives from the sun, and the light and heat which the earth receives?
12. At what rate per hour does Venus move around the sun? page 145.

## XV. OF THE EARTH, ⊕.

1. What is the figure of the earth? page 70.

2. Why is the earth represented by a globe? page 76.

3. What proofs have we that the earth is globular? pages 71, 72.

4. What would be the elevation of Chimboraço, the highest of the Andes mountains, on an artificial globe of 18 inches diameter? page 72, the note.

5. What is a spheroid, and how is it generated? page 73, the note.

6. What is the difference between the polar and equatorial diameters of the earth? page 74, and the note.

7. What is the length of a degree? pages 75, 76, and the note.

8. What is the use of finding the length of a degree, and how can the magnitude of the earth be determined thereby? page 75.

9. Who was the first person who measured the length of a degree tolerably accurate? page 75.

10. What is the length of a degree according to the French admeasurement? page 76, the note.

11. In what time does the earth revolve on its axis from west to east? page 77, and *Def.* 61, page 36, and the note.

12. What is the diameter of the earth; what is its circumference, and how are they determined? page 76, and the note.

13. What proofs can you give of the diurnal motion of the earth? pages 77, and 78.

14. How do you explain the phenomena of the apparent diurnal motion of the sun? page 78.

15. What proofs can you give of the annual motion of the earth? page 79.

16. What is the distance of the earth from the sun, and how is it calculated? page 80, and the note.

17. At what rate per hour does the earth travel around the sun? page 81.

18. At what rate per hour are the inhabitants of the equator carried from west to east by the revolution of the earth on its axis, and at what rate per hour are the inhabitants of London carried the same way?

19. How do you explain the motion of the earth around the sun? page 81.

20. How do you illustrate the phenomena of the different seasons of the year? page 82.

## XVI. OF THE MOON, ☽.

1. How many kinds of lunar months are there? page 146.
2. What is a periodical month? page 146.
3. What is a synodical month?
4. When is the eccentricity of the moon's elliptical orbit the greatest?
5. When is the eccentricity of the moon's elliptical orbit the least?
6. Whether does the motion of the moon's nodes follow, or recede from the order of the signs? page 147.
7. In how many years do the moon's nodes form a complete revolution around the ecliptic?
8. In what time does the moon turn on her axis?
9. What is the libration of the moon?
10. Is the path of the moon convex, or concave towards the sun? page 148.
11. Please to explain the different phases of the moon? pages 148 and 149.
12. What point on the earth has a fortnight's moonlight and a fortnight's darkness, alternately? page 149.
13. What is the moon's mean horizontal parallax, and at what distance is she from the earth? page 150.
14. What is the magnitude of the moon when compared with that of the earth?
15. How many miles is the moon in diameter?
16. In how many days does the moon perform her revolution around the earth, and at what rate does she travel per hour? page 152.
17. In what manner have astronomers described the different spots on the moon's surface?
18. Have not astronomers discovered volcanoes, mountains, &c. in the moon?

## XVII. OF MARS, ♂.

1. What is the general appearance of Mars? page 153.
2. In what time does Mars revolve on his axis?
3. In what time does Mars perform his revolution around the sun, and at what rate does he travel per hour? pages 153 and 154.

4. How far is Mars distant from the sun? page 154.
5. How many miles is Mars in diameter?
6. What is the comparative magnitude of Mars and the earth?

### XVIII. OF CERES ⚳, PALLAS ⚴, JUNO ⚵, AND VESTA ⚶,

1. When and by whom was the planet, or Asteroid, Ceres discovered? page 155.
2. How many miles is Ceres in diameter?
3. What is the distance of Ceres from the sun, and what is the length of her year?
4. When and by whom was Pallas discovered? page 155.
5. What is the diameter of Pallas in English miles?
6. What is the distance of Pallas from the sun, and the length of her year?
7. Who discovered the planet Juno? page 155.
8. How far is Juno distant from the sun, and what is the length of her year?
9. By whom was Vesta discovered?
10. What is the length of Vesta's year, and how far is she from the sun?

### XIX. OF JUPITER, ♃, &C.

1. In what situation is Jupiter a morning star, and in what situation is he an evening star? page 156.
2. In what time does Jupiter revolve on his axis?
3. What are Jupiter's belts?
4. In what time does Jupiter perform his revolution around the sun, and at what rate per hour does he travel? page 156.
5. What is the distance of Jupiter from the sun?
6. What is the diameter of Jupiter in English miles?
7. What is the comparative magnitudes of Jupiter and the earth?
8. What is the comparison between the light and heat which Jupiter receives from the sun, and the light and heat which the earth receives? page 157.
9. How many satellites is Jupiter attended by? page 157.
10. By whom were the satellites of Jupiter discovered?

11. In what time do the respective statellites perform their revolutions around Jupiter?

12. In what manner are the longitudes of places determined by the statellites of Jupiter? page 157.

13. Please to explain the configuration of the satellites of Jupiter as given in the XIIth page of the Nautical Almanac.

14. How was the progressive motion of light discovered? page 159.

## XX. OF SATURN, ♄, &C.

1. What is the appearance of Saturn when viewed through a telescope? page 160.

2. In what time does Saturn perform his revolution around the sun, and at what rate does he travel per hour?

3. What is the distance of Saturn from the sun?

4. How many English miles is Saturn in diameter, and what is his magnitude compared with that of the earth? page 161.

5. What is the comparison between the light and heat which Saturn receives from the sun, and the light and heat which the earth receives?

6. In what time does Saturn revolve on his axis?

7. How many moons is Saturn attended by, and by whom were they discovered?

8. Pray is not the seventh satellite the nearest to Saturn, and, if so, why was it not called the first satellite? page 161.

9. What is the ring of Saturn, and how may it be represented by the globe? page 160.

10. By whom was the ring of Saturn discovered?

11. In what time does the ring of Saturn revolve around his axis?

## XXI. OF THE GEORGIAN PLANET, ♅, &C.

1. When and by whom was the Georgian planet discovered? page 163.

2. What is the appearance of the Georgian when viewed through a telescope? page 163.

3. In what time does the Georgian planet revolve around the sun, and at what rate per hour does it travel?

4. What is the comparative magnitude between the Georgian planet and the earth?

5. How many satellites belong to the Georgian?

6. By whom were the satellites of the Georgian discovered, and in what order do they perform their revolutions around the planet? pages 163 and 164.

N. B. *The tutor may extend these questions to the Geographical Theorems, page* 59, *to Chap. V. VI. VII. VIII. and IX. Part I., and to Chap. I. II. III. IV. and VI. Part II.; also to the same manner of solving the different problems, &c.*

FINIS.

Plate II.

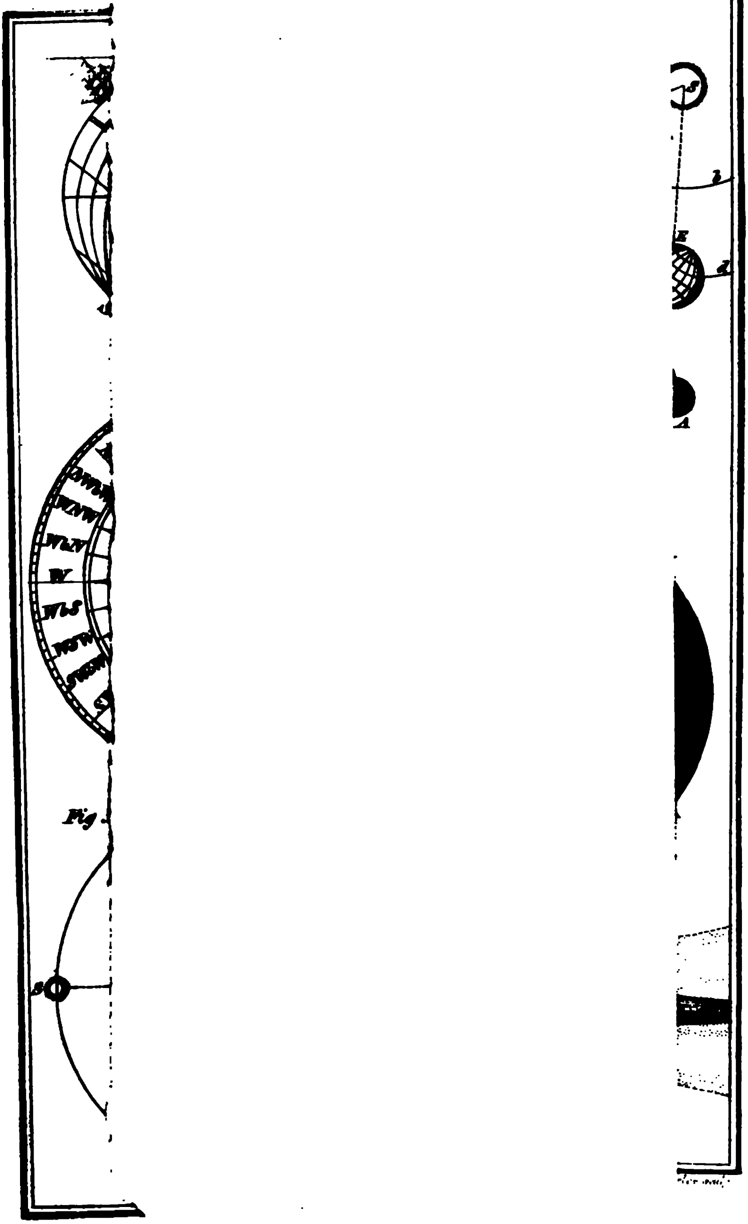


Plate II.

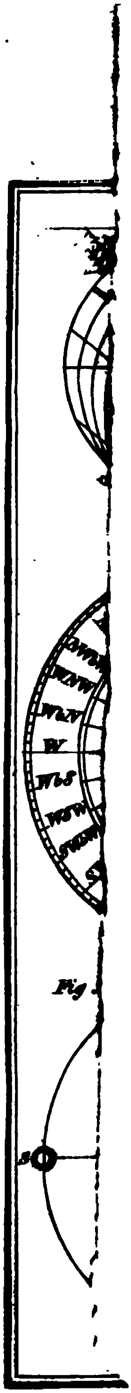
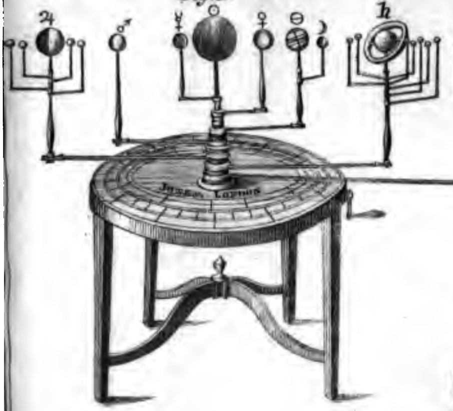
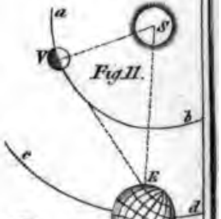
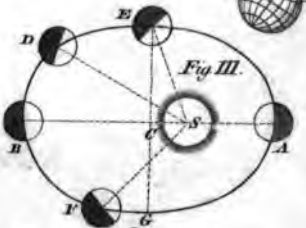


Plate II.

Fig. I.







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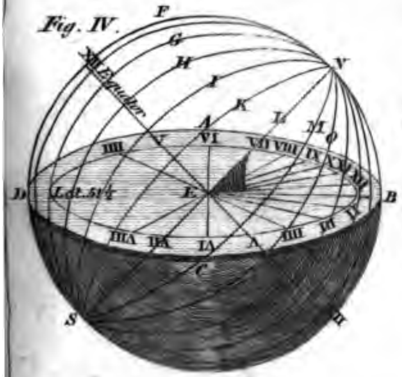


Fig. V.

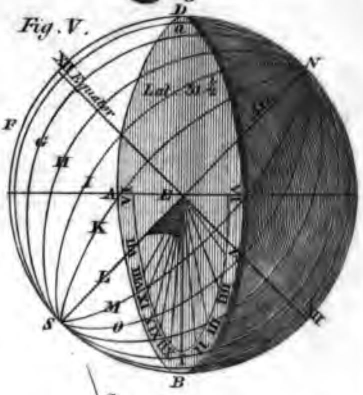
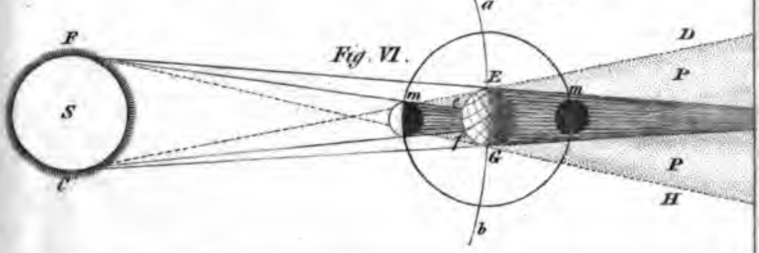


Fig. VI.



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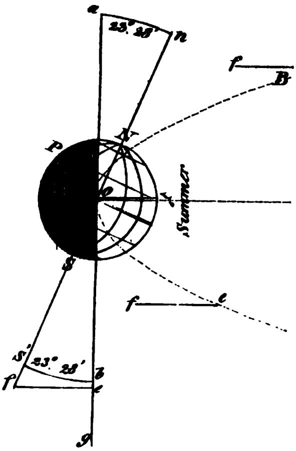

Fig. V.